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with the Assistance of
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Prof. Persifor Frazer, D.Sc., Prof. Edwin J. Houston, Theo. D. Rand,
Prof. Coleman Sellers, Prof. H. W. Spangler, Committee on Publications,
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Dr. Wm. H. Wahl, Secretary of the Institute.

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VOL. CXXXII. JULY, 1891. NO. 1

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VAUCLAIN'S COMPOUND LOCOMOTIVE.

[*Abstract of the Report of the Committee on Science and the Arts.*]

[No. 1,555.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 3, 1890.

The sub-committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred, for examination and report,

SAMUEL M. VAUCLAIN'S COMPOUND LOCOMOTIVE STEAM ENGINE,

respectfully report that they have examined the same and find as follows:

The invention is the subject of United States Letters-Patent granted to Samuel M. Vauclain, respectively numbered and dated as follows: Nos. 406,011 and 406,012, both dated June 25, 1889, and No. 431,860, dated July 8, 1890.

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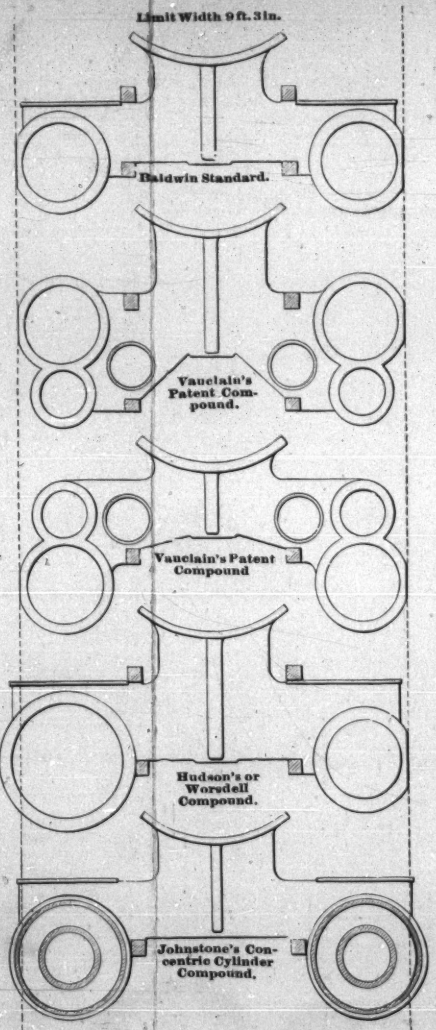
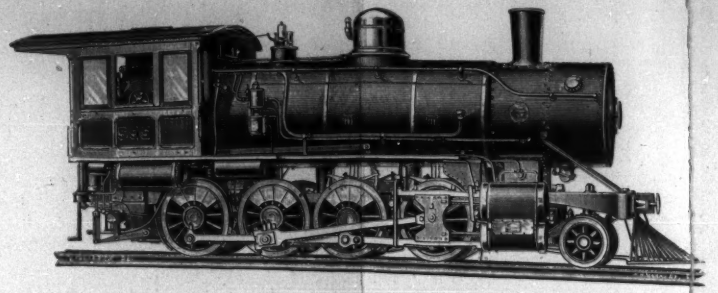
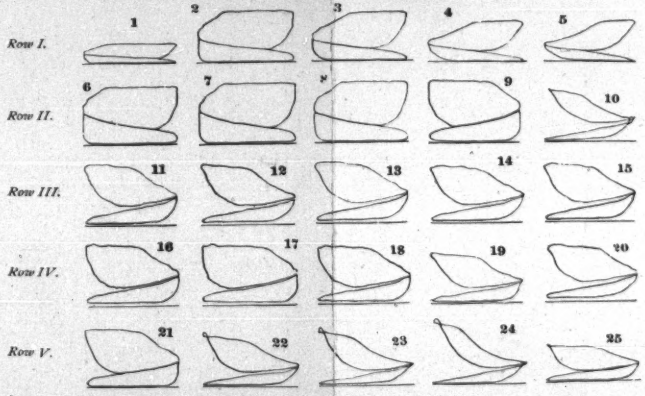




Indicator Diagrams taken upon Lehigh Valley and Pennsylvania Railroad, May 13 to 21, 1891.



Row I.—Philadelphia and Reading R. R., Preliminary Trial, May 10, 1891.

No. 1 speed not noted.
Nos. 2 and 3. . . . . 60 revolutions per minute or 9·11 miles per hour.
No. 4, ... 84 " " 12·74 " "
" 5, ... 72 " " 10·92 " "

Row II.—Lehigh Valley R. R., Mountain Grade, May 14, 1891.

No. 6, ... 54 revolutions per minute or 8·19 miles per hour.
" 7, ... 60 " " 9·11 " "
" 8, ... 66 " " 10·01 " "
" 9, ... 90 " " 13·65 " "
" 10, ... 150 " " 22·75 " "

Row III.—Pennsylvania R. R., Philadelphia to Harrisburg, May 17, 1891.

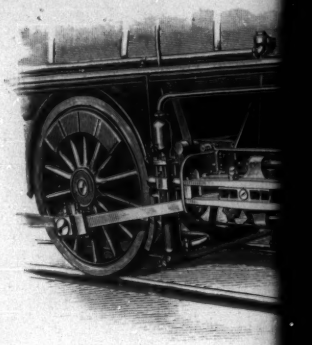
No. 11, ... 126 revolutions per minute or 19·11 miles per hour.
" 12, ... 132 " " 20·02 " "
" 13, ... 156 " " 23·66 " "
" 14, ... 162 " " 24·57 " "
" 15, ... 162 " " 24·57 " "

Row IV.—Pennsylvania R. R., Harrisburg to Altoona, May 18, 1891.

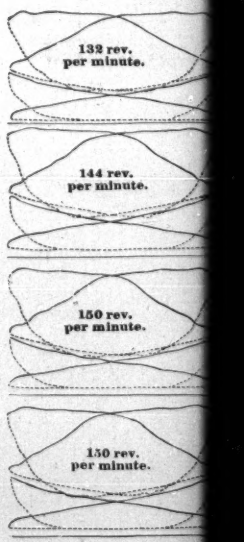
No. 16, ... 102 revolutions per minute or 15·47 miles per hour.
" 17, ... 108 " " 16·38 " "
" 18, ... 132 " " 20·02 " "
" 19, ... 138 " " 20·95 " "
" 20, ... 180 " " 27·30 " "

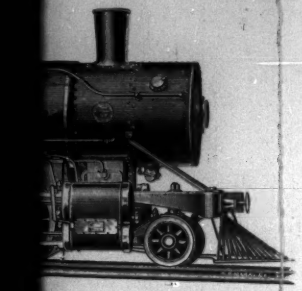
Row V.—Pennsylvania R. R., Altoona to Harrisburg, May 20, 1891, taken by Test Department of P. R. R.

Nos. 21 and 22 speed not noted.
No. 23, ... 250 revolutions per minute or 37·85 miles per hour.
Nos. 24 and 25 speed not noted.

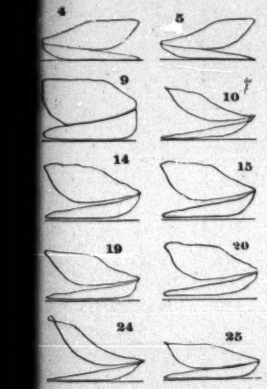


Indicator Diagrams Taken





y and Pennsylvania



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" 12·74 " "
" 10·92 " "

e, May 14, 1891.

ute or 8·19 miles per hour.
" 9·11 " "
" 10·01 " "
" 13·65 " "
" 22·75 " "

isburg, May 17, 1891.

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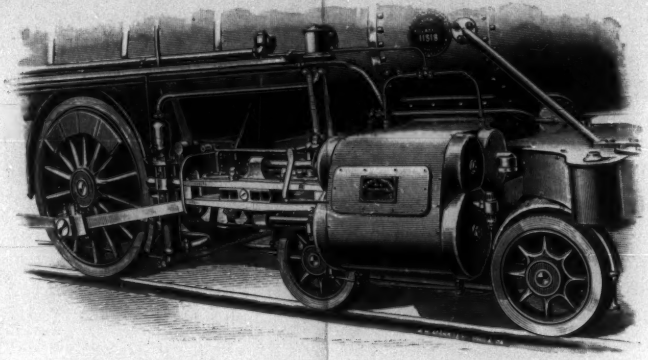
" 20·02 " "
" 23·66 " "
" 24·37 " "
" 24·57 " "

oona, May 18, 1891.

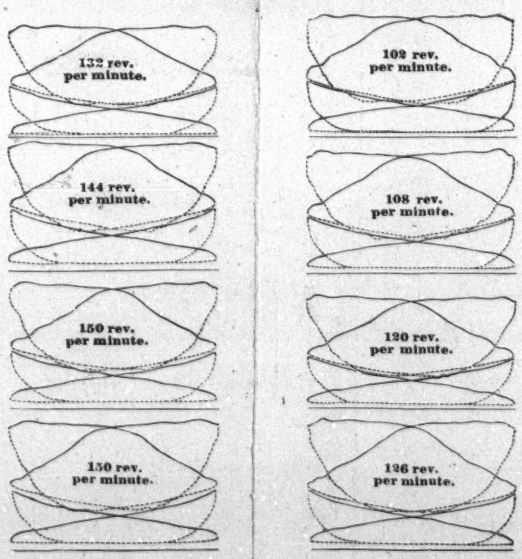
ute or 15·47 miles per hour.
" 16·38 " "
" 20·02 " "
" 20·95 " "
" 27·30 " "

o, 1891, taken by Test Depart-

ute or 37·85 miles per hour.

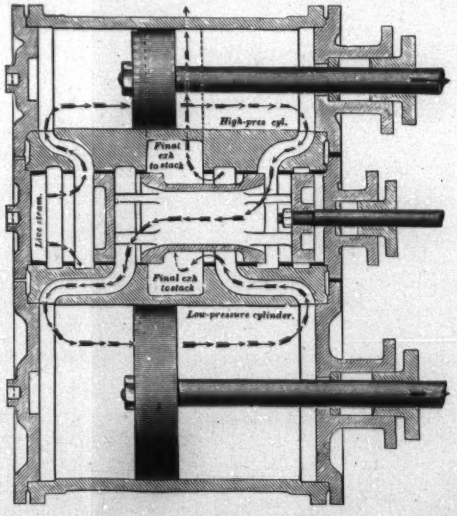


Indicator Diagrams Taken on Philadelphia & Reading Railroad, May 28, 1891.


132 rev. per minute.
144 rev. per minute.
150 rev. per minute.
130 rev. per minute.
102 rev. per minute.
108 rev. per minute.
120 rev. per minute.
126 rev. per minute.

VAUCLAIN'S COMPOUND LOCOMOTIVE ENGINE.

Diagram Showing Compound Cylinder and Piston Slide Valve.



The invention is illustrated in the drawings of said patents, and has been thoroughly tested in two engines built by the Baldwin Locomotive Works of this city, one of which your committee have examined in use upon the Baltimore and Ohio and Schuylkill River East Side Railways.

The engine, in general construction of boiler, furnace, frames, valve-gear, driving and truck-wheels, is the same as the Baldwin Standard passenger engines.

The difference between the Vauclain engine and the Standard engine is entirely in the cylinders, pistons, cross-heads and valves.

The general appearance of the engine is shown in the frontispiece, *Fig. 1*, which represents the engine made for the New South Wales Government Railway, from which diagrams and results of tests here published were taken as hereinafter stated. The proportion and relation of the cylinders in size and position to each other and their attachment to the crosshead and the forms of the crosshead are depicted in *Fig. 2*, and susceptible of variation, as shown in *Figs. 3* and *4*, for differing requirements of service.

The valve is of the type known as piston valves, consisting of a hollow plug with cylindric rims at proper intervals fitting in a hollow cylinder with apertures registering with the rim of the plugs leading to and from the ends of the cylinders, from the steam pipe and to the exhaust pipe.

In *Fig. 5* is shown a lengthwise central section of the valve, valve seat and cylinders, with arrows indicating the direction of the flow of steam which shows the manner in which steam enters the high-pressure cylinder and propels the piston in it, and on the return stroke passes through a central chamber in the valve to the opposite ends of the low-pressure cylinder, where it expands and propels the large piston, and in the next stroke passes through a circular groove in the centre of the valve, and is discharged through the exhaust port and exhaust pipe. The same operation takes place in both ends of the cylinder, the steam from the front of the high-pressure cylinder propelling, by its expansion, the piston in the back end of the low-pressure cylinder, and the steam from the back end of the high-pres-

sure cylinder propelling by its expansion the low-pressure piston from the front end.

The effect of conducting the different grades of expansion in separate cylinders is to avoid loss of heat from the steam conducted away by the cylinder and consequent reduction of force and waste of power.

The reason of this is obvious when it is considered that the temperature of steam lowers as the expansion progresses to lower pressures, and where the expansion takes place from the highest pressure to the lowest in the same cylinder, an undue portion of the heat of the high-pressure steam when admitted to the cylinder is expended in heating the cylinder above the lower temperature, resulting from the lower pressure steam expanded in it, and discharged from the preceding stroke.

In the compound engine the variations of pressure and attendant temperature in each cylinder is less, so that the absorption of heat from the steam by the cylinder is diminished.

Above and beyond this, a non-compound locomotive engine does not cut off steam and realize any economy by using it expansively, unless the engine driver adjusts the reversing bar and connected link motion, so as to cut off the steam at an early age in the piston stroke.

To enable a locomotive engineer to start, it is needful to adjust the link so that steam will reach the cylinder from the boiler nearly to the end of the piston stroke, motion of the engine being established, the link and the reversing bar being shifted towards a central position, and the throttle wide open, steam at high pressure enters the cylinder, is cut off early in the stroke, and expands to the end. This is troublesome where stops are frequent and is often neglected.

In a compound engine, on the contrary, the expansive working of the steam is compulsory, and does not depend so entirely on the attention and care bestowed by the driver.

The steam of boiler pressure flowing into the high-pressure cylinder of the compound engine further in the stroke than it does in the non-compound, a less reduction of

pressure occurs during the early and middle part of the stroke, which is true of all compound engines, and is here referred to as distinguishing the operation of compound from non-compound engines. It should here be borne in mind that it is essential in locomotive engines that the piston should near the termination of its stroke meet an elastic resistance to arrest the momentum acquired during the middle part of the stroke, or otherwise it would discharge such momentum in the crank pin and shaft, and impair or break them—this also is true of both compound and non-compound engines, and, excluding the latter part of the stroke from consideration, the force imparted to the crank pins throughout the stroke varies less in a compound than in a non-compound locomotive working expansively.

The proportion of lineal motion of the piston, to rotative motion of the journals of both the shaft and the crank pin is greatest near the centre of the stroke so that with higher pressure near the centre of the stroke than at the end, the transmission of the force of the steam to the shaft and wheels is attended with less waste of force in journal friction, a statement which can be readily verified by a comparison of indicator tests with brake tests upon the two classes of engines as employed in stationary service.

A by-pass pipe connects the opposite ends of the high-pressure cylinder, and, close to the points of insertion into the cylinders, is provided with valves controlled by the engineer, which are opened in starting the engine so as to permit steam to reach the low-pressure cylinder before motion of the pistons commences. These valves are closed during the normal working of the engine and by their use the engine starts promptly and readily.

The relative effects of the two modes of operating are shown in diagrams taken from both types of engines. In the non-compound engine, the pressure diminishes from an earlier point in the piston stroke, whilst in the compound engine it continues much further in the stroke with better mechanical effect.

The valves in the Vauclain engine examined by your committee were fitted with simple ring packings inserted

by springing them into grooves turned in the plug, and expanded by their own elasticity. There was very little, if any, force required to reverse the engine, when the throttle was open and full steam pressure upon the valve. In this respect it compares favorably with other engines, which require either the steam to be shut off before the reversing, or else a steam operated reversing gearing to be used.

For the performance of the same amount of work, the Vauclain compound engine requires less steam than the Standard engine, and therefore maintains steam pressure more easily, and has, after several months' use, demonstrated the most satisfactory running upon heavy fast passenger service and has repeatedly, during the tests by Mr. Barrus, run at the rate of a mile in forty-eight seconds.

The exhaust does not appear to be so noisy or with such strong impulses upon the draft, but at all times furnished all the draft required for combustion.

This engine rolls easily when cutting off close or with the reversing lever near the central position, and avoids the resistance of the piston to motion experienced in other engines in like adjustment.

The performance of this engine shows a decided economy in fuel, with a diminished requirement for feed water for the work done, the average fuel saving in four round trips between Philadelphia and Washington being very nearly fifteen per centum (within one-tenth of one per cent.). This, it should be borne in mind, is in competition with the best procurable engine, expanding steam in each single cylinder, having precisely the same steam generating apparatus.

The Vauclain compound locomotive for freight services, shown in accompanying illustration, has been tested upon the Pennsylvania and upon the Lehigh Valley Railways, and the diagrams and tabulated results of the tests are printed herewith, since which time the same engine has made a trial trip from Philadelphia (Belmont Station), to Reading, with an unusually large train, to which trip the entire Committee on Science and the Arts were invited, and several members made the journey and participated in the tests. A series of diagrams were taken upon this trip by Mr.

Shaw, of this committee, and Mr. Kenneth Rushton, copies of the diagrams are also printed herewith.

It will be observed in the diagram last referred to, that the exhaust line or piston resistance lines are marked in dotted lines and reversed in direction from the diagrams so that the eye may readily appreciate the difference of pressure operative upon the opposite sides of the piston at every point of the stroke, such dotted lines being reversed or transferred over, ordinates from the back pressure lines to the steam line will represent the difference between propelling force of steam and back pressure, or the net operative force transmitted to the piston.

In the tests made by the Vauclain compound engine very little of fuel or cinders accumulated in the smoke box as compared with the standard or non-compound engine and no sparks were observed to escape from the chimney.

The compound locomotive engine is at present such an innovation in railway practice as to command general interest and attention, and, to your committee, appears to require for a clear understanding of a report on the merits of the particular invention under consideration, that a review of the state of the art should be submitted therewith, to show the reasons which govern your committee in forming their conclusions upon the merits of the applicant's invention and facilitate intelligent action upon the report. Although well aware that such a review of the state of art is unusual, your committee are of the conviction that it is necessary and fully justified by the importance of the subject and worthy of both the labor of making it and of your attention in considering it.

They have accordingly prepared a concise abstract of each of the patented compound locomotive inventions of record in the British and United States Patent Offices, which they herewith submit, noting the characteristic peculiarities of each and showing a copy of the prominent figures of the drawings of each patent.*

* This abstract of state of art embraces fifteen pages of text besides several hundred figures of illustrations, and is too voluminous to insert in this journal. It is accessible in the Library of the Franklin Institute, together with copies of all the data before the committee and full copies of all patent specifications and drawings examined by the committee.

Date.	No. of Trip.	Railroad.	No. of Cars.	Weight of Train.	Time Consumed.	Time Detained.	Running Time.	Coal Burned.	Water Evaporated.	Coal per Car Mile.	Water per Pound Coal.	Coal allowed by R. R. Co. per Car Mile.	Engine Numbers.	Type.	Locality.
				tons. cwt.	*hr. min.*	*hr. min.*	*hr. min.*	*tons. cwt.*	*tons. cwt.*						
May 13,	1	L.V.	29	257 10	1 20	— 20	1 —	— 17	6 16	5·4	8·00	—	595	Compound	Sugar Notch to Fairview.
May 13,	2	L.V.	32	284 2	1 31	— 12	1 20	— 18	7 6	5·4	8·11	—	595	Compound	Sugar Notch to Fairview.
May 14,	3	L.V.	32	295 14	1 11	— —	1 11	— 19	6 18½	5·5	7·28	—	595	Compound	Sugar Notch to Fairview.
May 14,	4	L.V.	32	295 14	— 59	— —	— 59	2 1	8 7½	11·9	4·08	—	458	Wootten	Sugar Notch to Fairview.
May 15,	5	L.V.	32	295 14	— 50	— —	— 50	— 13	6 11	3·7	10·0	—	595	Compound	Sugar Notch to Fairview.
May 15,	6	L.V.	36	319 6	1 4	— —	1 04	— 14½	6 17	3·7	9·4	—	595	Compound	Sugar Notch to Fairview.
				net tons.				*pounds.*	*pounds.*						
May 17,	7*	P.R.R.	E 50 C. 90 H. — 563 C. 1022 H.	8 0	2 33	5 27	11,800	80,925	3·5	6·8	4·6	595	Compound	Philadelphia to Harrisburg.
May 18,	8	P.R.R.	E 80	880	9— 5	1 32	7 37	13,000	125,330	2·5	9·6	4·6	595	Compound	Harrisburg to Altoona.
May 19,	9	P.R.R.	E 27	338	No record on account of detentions.								595	Compound	Altoona to Gallitzin.
May 19,	10	P.R.R.	E 40	404	1 22	— —	1 22	2,950	20,900	12·2	7·0	—	595	Compound	Altoona to Gallitzin.
May 20,	12*	P.R.R.	L 65 M. 69 H. — 2483 M. 2654 H.	11 15	3 10	8 05	9,150	67,083	1·04	7·33	4	595	Compound	Altoona to Harrisburg.
May 21,	14*	P.R.R.	L 66 C. 30 P. — 2425·4 C. 1053 P.	10 30	2 47	7 23	9,100	68,890	2·07	7·5	4·6	595	Compound	Harrisburg to Philadelphia.

* Trip No. 7 consisted of 50 cars, Philadelphia to Columbia, and 90 cars, Columbia to Harrisburg.
Trip No. 12 consisted of 65 cars, Altoona to Mifflin, and 69 cars, Mifflin to Harrisburg.
Trip No. 14 consisted of 66 cars, Harrisburg to Columbia, and 30 cars, Columbia to Philadelphia.

The construction of the Vauclain engine cylinders, valves, guides and crossheads, permits of their easy adaptation to the frames of existing Standard engines, and allows such diameters of low-pressure cylinders as to derive the best effect from the expansion of steam, a feature inadmissible in engines of the Hudson type, known popularly as Worsdell's engine, having two unequal cylinders, one on each side, as shown in the diagram on frontispiece, marked *Fig. G.*

This diagram shows above, the position of the cylinders of a Standard engine, and those of a Hudson* or two cylinder compound engine, annular cylinder engine (F. W. Johnstone's), and those of forms of the Vauclain engine, with the lines of limitation of width drawn upon them, all being of equal capacity of piston duty.

It will be seen that the Hudson low-pressure cylinder, whilst having its flange close to the frame, projects six inches beyond the lateral limit of 9 feet 3 inches and any reduction of the diameter of the low-pressure cylinder, impairs both the economy and capacity of the engine.

The Vauclain engine is applicable to the framing in general use upon American locomotives.

All parts of it are of simple and substantial construction and easy of access for lubrication, inspection and repairs.

It can be applied to locomotives having outside cylinders without increasing the entire breadth of the engines at the cylinders beyond the restrictions made necessary by bridges, tunnels and trains upon parallel tracks.

The transfer of steam from the low to the high-pressure cylinder is effected by the shortest practicable conduit. The valve construction is simple and, being balanced, requires a minimum of force to work it, irrespective of the steam pressure upon it.

The distribution of force upon each side of the engine is equal.

Each side of the engine is capable of working, when the

* The two-cylinder type of compound engine, popularly known as the "Worsdell," was first patented by Mr. W. S. Hudson, of Paterson, N. J. (Superintendent of the Rogers Locomotive Works), March 11, 1873.

other is disconnected, and when so operated, can produce a draft sufficient to maintain effective steam generation for running purposes, a feature of decided importance in cases of accident disabling the engine of one side.

The engine always starts promptly and steams readily with the diminished exhaust pressure, the volumes of the exhaust being greater than with the Standard or non-compound engine and occurring twice as often in the revolution of the shaft, as in either the Webb or Hudson type of engine.

It is not pretended that this compound engine imparts any new properties to the steam that is used in it, so as to surpass other well-proportioned compound engines, in degree of expansion and consequent economy of steam, but that it does diminish the clearance space between the high- and low-pressure pistons, and promptly proceeds with the expansion in the low-pressure cylinder, whilst in other types of engines the exhaust from the high-pressure cylinder must be retained in a receiver, to await the opening of the valve admitting it to the low-pressure cylinder.

In engines of the Hudson type, with the cranks at an angle of 90° this is about one-half of a stroke of the piston. In the Webb engine, during each revolution, there are four deliveries of steam from the high-pressure cylinder, to the receiver or pipe leading to the low-pressure cylinder, while there are but two deliveries of steam to the low-pressure cylinder and since there is no mechanical connection to transmit motion of the wheels driven by the high- and low-pressure cylinders, except the adhesion of the wheels to the rails, there is no regular timing of the exhaust of the high- and low-pressure engines, for they are, to all intents and purposes, in mechanical connection, independent of each other, except in steam supply.

The Vauclain engine, on the contrary, takes steam immediately from the high- to the low-pressure cylinder, and the two pistons being connected, move together and require no receiving chamber in which to store the steam and in which the steam expands without useful effect.

Claims are urged for engines having a receiver exposed

to heat from the products of combustion in the smoke box for reheating or superheating the steam, but when it is considered how much steam is to be heated, how little time it is exposed to the heat, and how low the temperature in the smoke box, with the gentler exhaust from the low-pressure engine, your committee is not impressed with its importance. The loss by expansion in the receiver is apparently as great or greater than any possible gain by the reviving action of the heat of the receiver.

A practical confirmation of the merits of the invention, as it impresses your committee, is to be seen in the rapid adoption of the engine by the roads that have tried them or observed them carefully as used by others. The number of engines in use and ordered for use after examination and tests, showing the avidity with which railways adopt them, confirms your committee in their conclusions as to the merits of the invention.

As compared with the two-cylinder compound of the Hudson type, the Vauclain is two distinct engines, having no connection with each other but the driving axle, and when either engine is disabled, the other can be operat,ed and the connected train moved, whilst with the Hudson or Worsdell type of compound, the two engines are necessarily interdependent, and when either is disabled, the exhaust through one cylinder only is inadequate to produce draft sufficient to generate steam.

The same difficulty appears in operating a single cylinder of the three-cylinder or Webb type of engines.

Whilst both the Hudson and Webb type of engines are capable of showing economical results, as operated in Europe, under prescribed favorable conditions, in the control of their inventors, they do not appear to meet the varied requirements of service demanded upon railways as operated in this country, and it has not yet been practicable to adjust the traffic to engines of fixed capacity for economic work.

Your committee, in conclusion, find that in view of the state of art, the Vauclain compound locomotive is a distinctly new and original type of locomotive. It is the most

marked departure from the usual construction of engines, that has elicited general satisfaction wherever introduced, and in view of the reliable and satisfactory performance in service under the largest variations of conditions, immunity from total disablement, ready adaptability within limits of space incapable of accommodating other compound engines, and general applicability to and utility in railway service, it is, in the opinion of your committee, deserving of recognition by the award of the Elliott Cresson Medal of the Franklin Institute, which they hereby recommend.

S. Lloyd Wiegand,
Luther L. Cheney,
William L. Simpson,
John E. Codman.

Adopted, June 3, 1891.

S. Lloyd Wiegand,
Chairman of Committee on Science and the Arts.

VAUCLAIN'S DRIVING- AND TRUCK-WHEEL CENTRES.

[No. 1,620.]

[*Report of the Committee on Science and the Arts.*]

The sub-committee, No. 1,620, of the Committee on Science and the Arts, to whom was referred for examination and report the improved method of making wrought-iron driving- and truck-wheel centres, patented by Samuel M. Vauclain, of Philadelphia, and practised at the Baldwin Locomotive Works, respectfully report that they have examined the said invention and the apparatus for operating it, and have inspected the product, specimens of which are herewith produced, and find as follows:

The invention is the subject of two Letters-Patent of the United States, respectively numbered and dated 408,056, July 30, 1889, and 420,842, February 4, 1890, granted to the inventor, Mr. Samuel M. Vauclain, of Philadelphia, Pennsylvania.

The object of this invention is to produce strong wheel centres of wrought iron, expeditiously and cheaply, of the

forms which theretofore had only been practicable to form by casting, and which had, as all iron castings have, a liability to fracture.

To concisely describe the process, they are drop-forged or swaged from parts previously rough-shaped, which are not only swaged or die-forged, but are simultaneously welded together.

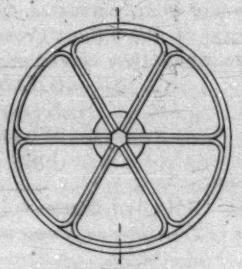


FIG. 1.

The invention is well described, and is illustrated in the specifications and drawings of the letters-patent, which are here reproduced, showing the parts as made in the rough, preparatory to assembling, heating and welding, and the finished wheel centres and sections thereof.

The parts are as follows: A cylindric band, shown

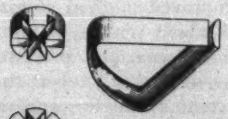


FIG. 3. FIG. 2. FIG. 5.

separately in *Fig. 4*, which forms the rim of the wheel shown in *Fig. 1*, a triangular bent piece, having a convex inner surface, the curved side, forming part of the rim, and each straight side, forming one-half of a spoke, shown in *Fig. 1*, and hub pieces, shown in *Fig. 3*, having radial grooves, into which the inner ends of the spokes are placed, it being

understood that the two contiguous parts enter into and form each spoke. The parts are placed together, as shown in *Fig. 1*, and small triangular drop-forged pieces shown separately in *Fig. 5*, are placed in the spaces left between the rim and the contiguous bends of the triangles.

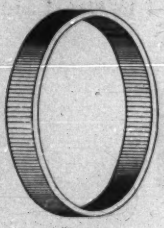


FIG. 4.

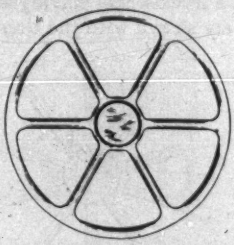


FIG. 6.

FIG. 7.

The parts, as assembled, are placed in a furnace and heated to a welding temperature and then placed in a bottom die, shaped like one-half of the finished wheel, and secure upon the anvil of a direct-acting steam hammer.

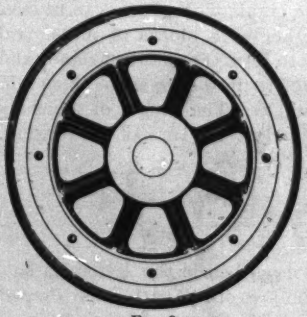


FIG. 8.

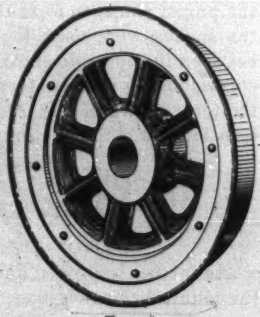


FIG. 9.

The upper die, which is a counterpart of the upper side of the finished wheel is attached to the ram of the steam hammer and guided so as to register with the lower die, is then forced down upon the hot metal and forces and welds the parts together, at the same time swaging them into the

shape of the wheel depicted in *Fig. 6*, and of section as shown in *Fig. 7*.

Any superfluous metal finds vent between the faces of the dies in the form of a thin fin or beard, which is easily removed with chisels. As above described, the wheel centre produced is a truck wheel having spokes of elliptic cross-section and are shown with the tires applied in *Figs. 8* and

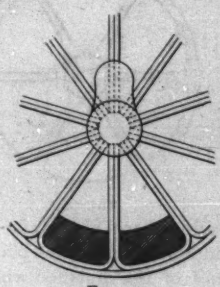


FIG. 10. FIG. 11.

9. For driving wheels, as at first made, bosses of metal, of the proper shape to form the crank, with grooves to fit over the spokes, were used, together with blocks of metal laid between the opposite spokes to form the counterbalance and corresponding recesses formed in the dies to shape them into the form shown in *Figs. 10* and *11*. The weight of the counterbalance was thus determined at the time of the forging.

FIG. 12. FIG. 13.

As further improved and described in the letters-patent, the counterbalance is made hollow, of two parts, each shaped as a segmental box, with notches in the edges to fit over the spokes, as shown in *Figs. 12* and *13*, and the metal for the crank boss introduced in similar manner, and the wheel produced is as shown in *Figs. 14* and *15*, with a hollow counterbalance, which was afterward adjusted in weight by the introduction of melted lead to suit the varying require-

ments of differing weights of connected parts in the engines, to which the wheels are applied. A finished driving wheel fitted with a tire is shown in *Fig. 16*.

The dies for swaging the wheels are made with a flat

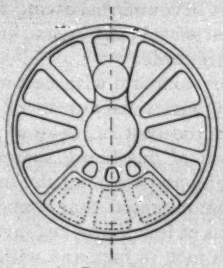


FIG. 14. FIG. 15.

bottom and rim, forming a bed into which the parts for the shaping of the spokes and rim are fitted in separate segments, the central boss and crank boss dies being of steel and the other parts of cast iron, so that by changing only a portion of a die, wheels of different proportions of hubs and

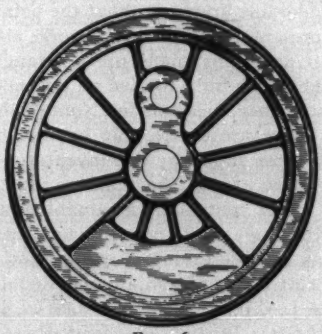


FIG. 16.

length and diameter of crank may be made, a feature of great importance when the variety of sizes and proportions demanded for the numerous classes of engines is considered in conjunction with the weight and cost of the dies.

The wheels as forged are soundly welded throughout, as is shown in the specimens submitted, cut in every part, so as to expose the parts involved in every weld.

They have all the desirable features of shape and convenience of adjustment in counterbalancing that heretofore were procurable by cast wheel centres, and such strength as to be practically indestructible.

In point of cost, they compare with cast-iron wheel centres as the price of rough iron bars or muck bars compare with the best pig iron, the cost of heating, welding, drop-forging and dressing-off of fins being somewhat less than that of moulding, casting and cleaning the iron castings.

Experience has demonstrated that sound and reliable welding is had with fins of less than one-fourth inch thick—more nearly one-eighth inch in fact, and with a variation in weight of the wheels of less than two per centum.

Your committee are well aware that wrought-iron locomotive and car-wheel centres have been made wherein segments of the rim were forged each with a spoke and segment of the hub and the several segments of the rim welded together. This was tedious and expensive work and required considerable dressing about the points of welding to make any presentable finish of the work; also that wheels having spokes and rims made up of triangles and rims riveted together, with hubs formed on the inner end of the spokes by casting have been made. None of these, although expensive to make, are comparable in strength, durability or finish, with those shown by this inventor.

Your committee are of the opinion that the Vauclain wrought-iron wheel centres are a valuable improvement in the art, contributing alike to economy and safety of railway service, and as such deserving of recognition by the award of the John Scott Legacy Premium and Medal.

LUTHER L. CHENEY, COLEMAN SELLERS, JR.
JOHN L. GILL, JR. JOHN HALL,
S. LLOYD WIEGAND.

Adopted, May 6, 1891.

S. LLOYD WIEGAND,
Chairman of Committee on Science and the Arts.

POSSIBILITIES OF APPLIED SCIENCE.

By Oberlin Smith.

[*A lecture delivered before the Franklin Institute, February 16, 1891.*]

[*Concluded from vol. cxxxi, p. 434.*]

The next general factor in the civilization of the race, which appears in my classification, is *trade*, or traffic, and, in its comprehensive sense, this term should include manufactures, which, abstractly considered, begin at the field and the mine, and consist simply of the buying and selling of labor. This field is, of course, too large to attempt to harvest in detail in a lecture like this. It may be well, however, to touch upon a few salient points, in addition to those improvements mentioned under other headings, which will inure to the benefit of traffic, such as better railways, ships, etc.

One improvement that we may expect in manufacturing of all kinds, is the standardizing of the articles made, both in regard to quality of material as well as in design and dimensions. How this can be universally brought about I leave for the students of social science to determine—in view of the fact that some unification of interests, and some submission to a central authoritative power, would be prerequisites. That a great deal of it should be done, is a fact patent to every engineer. Such standardizing not only cheapens goods, but makes them better and facilitates the interchange of parts where modifications and repairs are desirable.

Among the improvements which I think are destined to appear along with other economies of ordinary commercial life is a considerable amplification of the "automatic-payment" idea, which started with the fare-box in omnibuses and street cars, and has become so popular in the way of nickel-in-the-slot machines, of all descriptions, and for all purposes—from weighing a baby to lighting one's cigar.

The primal idea in all these contrivances is simply to save the time of a salesman, and I think we are destined to see the principle applied to many things where its use is now almost inconceivable. Very possibly we shall have special coins prepared for such work which will in themselves act as keys to unlock the devices which they seek to enter. The development of this idea may give us tickets, to carry as coins, which will let us into a ferry-house or railway station without the danger of irritating the nerves of a guardian angel tending its gates.

In our counting-houses, we are doubtless destined to use much more machinery than at present. Our typewriters will be improved, let us hope into accuracy and noiselessness; we shall use mechanical and electrical calculating machines for adding our ledgers, and the phonograph will very likely relieve our stenographers of their most arduous duties. This latter machine is, of course, at present in a somewhat embryotic state, but it seems to me that its future prospects are almost boundless. The wonders which it is to accomplish have been so often said and sung by magazine writers and by scientists, that it is scarcely worth while to enter into all the probable details here. In general, the chief commercial uses which are likely to be made of this greatest discovery of the nineteenth, or any other, century will be not only the dictation of letters, to be afterwards printed or written, and the mailing of the records direct, for use in other people's instruments, but the keeping of business records and statistics. Not speaking now of its domestic, artistic, literary and historical uses, I will only say further that it probably is destined to occupy a very important field in the taking of legal testimony—as a stenographer that "cannot tell a lie." I have called this wonderful machine a "discovery" because, in its primal stage, it was this, rather than an invention. The accomplished Edison found out, for the first time in the history of the world, that articulate sounds, with all their delicate individualities, *could be* translated into simple mechanical undulations—and this by machinery of ideal simplicity. The invention came afterward, and must still

go on, further and further toward perfection. This perfecting process will very likely bring about devices whose action will be electrical rather than mechanical, thus securing a delicacy otherwise unattainable. In this form it may be made a part of a self-recording telephone—so that it may be talked to at any distance.

Boundless also seem the future possibilities in regard to the telegraph, the telephone and those various tel-something-or-others which are to come, whose function it will be to transmit our handwriting, our printing and our pictures; and, in a higher state of development, perhaps views of our faces and surrounding objects. Indeed, who knows but that the senses of touch, taste and smell may yet be transmitted—by politeness of the same mysterious Mercury who now carries our voices over thousands of miles of forest, sea and plain? In the telephone itself, we fondly look for some improvement, at least those of us who are amateurs. The ideal telephone would of course be international, and its current as good a voice transmitter by ocean as by land. We must look to science to cure it of its *mal de mer*, and to make it perform its functions on land so that a part at least of the conversation will consist of something else but "hellos!" We must have it so good that no sound can be heard but the voices of the two individuals who are using it for the time being, and so cheap that it can be in every house having any pretensions to affording the ordinary decencies of life. May we not hope sometime to have it so arranged with regard to its exchange system that any user can, by the moving of a pointer to some number, or combination of numbers, put himself in communication with any desired correspondent in any part of the civilized world? And may this not happen *while* others are using the same wire, and without interference? All this will doubtless seem to the "practical" electrician of to-day as the rhapsody of an enthusiast, but stranger things than this have already happened, and there is no knowing what brilliant results may from time to time be achieved as we follow out, more fully than heretofore, the general principle of running different kinds and phases of currents through the same wire

at the same time—on top of one another, so to speak. The embodiment of this principle has already made famous an Edison, by the invention of quadruplex telegraphy. It has enabled us to send an "induced" message, in train-telegraphing, over a wire through which ordinary messages are passing at the same time. By it, a Gray sends a dozen musical tones of different pitches through a wire in which they don't get mixed up at all.

In regard to *travel*, we perhaps have before us more brilliant possibilities than in almost any other field of human achievement. For rapid land-travel we shall probably have some modification of our present railways, which will be as far ahead of them in refinement of construction and action, as is a polished lady's bicycle, of rubber and steel, beyond the clumsy wooden wheel-barrow of the navvy. This comparison I have made before in an article upon "Reform in Railway Construction," which was published by the *Forum*, in its issue of January last, and to which I refer any one interested, for my ideas on this subject, in detail. It seems to me beyond question that some succeeding generation, perhaps the next, will travel at a speed of somewhere between 100 and 200 miles per hour. The motive-power will probably be electricity, applied to the axles of the cars themselves, which cars will be incombustible, comparatively non-smashable and of such low specific gravity as not to carry some five tons of dead weight for each passenger, as do our present Pullman trains. There will be some electric, automatic, block-system to prevent collisions, and the cars and track will be interlocked with such harmonious relations that derailment will be impossible. We shall not then drag cars made purposely heavy, so that they may ballast down narrow wheel-flanges to their function of keeping us out of eternity. They will of course be warmed and lighted by the same current which drives them, and will, let us hope, be in direct telegraphic and telephonic communication, accessible to the passengers, not only with all the stations along the line, but with other cars running thereon. A further development of this system may result in each train and station having a chart of the road upon which will move,

automatically, dots, representing all trains, thus enabling many eyes at once to constantly watch for any dangerous contiguity thereof.

Should we by that time have learned to produce our electric currents from the coal direct, the cost of travel will be reduced to a figure marvellously low. This will be due not only to the small cost of motive-power, but also to the enormous increase of the travelling habit, due to the comfort, safety and speed attainable.

There is no reason why some of the methods which will so facilitate travel upon railways should not be extended to ordinary wagons, omnibuses and carriages—as also to tricycles and bicycles. All of these can advantageously be run by electric motors—providing we can get storage batteries sufficiently light, primary batteries sufficiently cheap, or line conductors sufficiently convenient.

In regard to water travel, the improvements that another generation may expect in our sea-going ships will consist, first of all, in absolute safety from fire and foundering, due to proper metallic construction and the division of the hulls into a sufficient number of air-tight cells in addition to its general division into large separate compartments. This latter point we have nearly reached now, but, as was proved last year in mid-Atlantic, not close enough to prevent the passengers on one of our safest and fastest steamers from indulging in profound meditations upon a Future life, during the three or four days succeeding the opening of a small hole in the ship's bottom. Had she been cut in two by a sister ship we probably should never have heard of the meditations in question.

In the second place, these ships of the future will probably be driven by electricity, through the means of a simple rotating armature fixed directly upon the shaft of the screw itself; that is, if the screw (or screws) still remains the best method of propulsion. Nothing simpler or smoother in its action than this can be imagined, and it will certainly be a welcome substitute for the vast mass of boilers, engines and pumps which now fill so large a part of the hold of a vessel. The source of electric current for driving the motors

of these three- or four-day "Atlantic liners," will probably be either storage batteries, placed in the extreme bottom and along the whole length of the hold, where they will serve as excellent ballast, or else the current will be generated by some direct process from coal or other fuel, either burned or otherwise chemically disorganized, during the passage. The latter method of course is after the similitude of our present primary batteries, but who can say that we may not after all revert to this original method of producing a current, when we have learned how to do it without using such expensive materials as zinc, for instance, for fuel. If, on the contrary, we use storage batteries it will be because we have by that time learned to make them enormously lighter in proportion to the power stored than we can now do, the present weight of some of them being over 100 pounds for each horse-power per hour. This is bad enough, but we obviously must not make a direct comparison with (say) two pounds of coal per horse-power hour, because the weight of furnaces, boilers, water and part of the engines can be omitted. The recharge of these batteries would of course take place during the time that the ship lay at her wharf, and could go on all day and night simply by connecting two wires to a pair of screw-cups in the ship, such screw-cups being her only visible relation with the-powers-that-be on shore. All this is now habitually done with scores of small pleasure boats on the Thames, but they cannot possess a very high efficiency.

The same current which drives our hypothetical ship will, of course, be available for loading and unloading cargo, pumping water, blowing and sucking air, hoisting sails (if there be any), loading cannon (should such a barbarism have survived into the electrical age), sounding signals, communicating with other ships by some system of water telephoning, warming the ship and cooking the dinners; also for lighting the ship with a daylight brilliancy, both below and above deck.

What we shall do in the way of submarine boats, is, of course, a matter of conjecture; but should they for any reason be desirable, either for purposes of war, or for

getting a little way under the surface to avoid sea-sickness, we can hardly doubt that our inventors will contrive ways to manage them safely. We have beaten in speed and endurance the animals on land; why should we not the fish within the sea? Jules Verne, in playful spirit of romance, has pictured such a boat, but it seems not beyond the bounds of possibility that our inventors will sometime, in this respect, out-distance his wildest speculations—especially as we have already made small ones which have remained for hours below the surface.

In regard to the construction of our future boats, we can only guess; but it seems not unlikely that science will develop some less crude method of building such a complex structure as the hull of a great vessel, with all its decks, bulkheads and other partitions, than the present piling together of hundreds of thousands of pieces, in the shape of plates and rivets and bars, that are obliged to be much heavier than would be the case were they not weakened by the very means used to hold them together. Possibly we may by that time develop some practical system of welding as a substitute for riveting, or (who knows), perhaps we may learn to make any metallic structures we desire, either small or great, in one piece complete, by the process of electro-deposition! These may be radical ideas, but who can say they are too much so, in the light of the very recent inventions for welding up the shells of large boilers, and for electro-depositing large balls and tubes?

The material of these boat- and ship-hulls of a coming age, whether made into one piece by riveting, soldering, welding, casting or depositing, may still be steel, as now. More likely, however, some better and less corrodable alloy will be made available. Very possibly its composition in large measure will be aluminum.

As before remarked, we have beaten the beasts upon the land, and, in some respects, the fish within the sea. Does not analogy tell us that sometime we shall also have beaten, in their own element, the birds of the air? I am aware that flying-machines, from the time of Daedalus down to

that of Darius Green, have been a butt of ridicule for all sensible people, and the pet weakness of many so-called cranks. It is nevertheless true that a bird is simply a machine, and when we properly learn the principle upon which he flies, and learn also to store as much power within a machine of proportionate weight, we shall be able to fly just as well as he does—or better. We must, however, abandon the notion of carrying a great bag of gas with us to form an obstruction against the air, and depend upon the same principles as does the bird. We have been amusing ourselves with gas balloons now for over a century and have gotten very little further along than did Montgolfier at the start. We occasionally paddle them about a little upon a still day, or in an exhibition building. Is it not time for us to stop all such nonsense and give our attention to scientific study and experiment? A lark couldn't fly carrying an inflated pillow-case. We cannot stop the wind blowing where it listeth—and taking gas-bags along with it.

Of course, we must accept the fact of the inherent danger of even a good flying-machine, in regard to collision and the possibility of falling should the machinery get out of order. Just as does a bird relinquish all hopes of happiness when a bullet, or another bird, or a stroke of heart-disease kills him in the air, so must our future aëronauts expect a great calamity should a collision occur in going rapidly at a high elevation. Possibly, however, the falling part of the danger might be modified by some system of self-acting parachutes. Here, too, with our mechanical birds, as in case of our future ships, we shall probably depend upon stored electric power for driving, lighting and warming, and shall construct in the lightest possible manner, with the lightest possible metal and other materials.

Learning is the next general subject in my list, but a difficult one in which to prophesy reforms due to inventive genius. Among other improvements which will assist in teaching us how to teach, and by which we may learn how to learn, is a more complete and systematic adoption of the general principle of standardization, making more uniform our systems of learning in our schools and colleges.

In classical education this has, of course, already been done, but in the comparatively new conditions of scholarship, as pertaining to the study of science, many changes for the better will doubtless be made.

Among the improvements of the future that we may expect to aid us in scientific scholarship will be some international unification of weights and measures, which must be even better than the French system; a spelling reform which will greatly lessen the difficulties of mastering language and save a great deal of printer's ink, etc. Another thing that we scarcely realize now is, I think, the use that could be made of the phonograph or some similar instrument, as a means of standardizing language, not only in different provinces of a country where a given language is spoken, but throughout different eras of time. This would go beyond all pronouncing dictionaries, which are, withal, only able to define the sound of a word or letter by referring to an assumed value for the character representing it. This assumption may, by sufficient care, be standardized for different places, but not for different centuries of time. Can words express the value that would now be set upon a few "phonograms" spoken in Rome and Athens 2,000 years ago —or a few more by Chaucer and Will Shakspere?

Another possible source of knowledge beyond our present dreams may consist in the invention of instruments by which we may hear sounds which are now too low, or too high, in the musical scale for our ears to recognize. Who can say what hidden stores of knowledge are lying fallow in these realms of sound that are all around us, but to which our ears are deafened.

In the field of *art*, meaning thereby the fine arts, we can hardly prophesy much change except that due to the natural evolution of the race itself. From this source, however, we must expect a greater love for, and more appreciation of all beautiful things. As this feeling grows it will demand that all streets and buildings in our cities be made beautiful; that our non-urban landscapes be not ruined by ugly houses and factories, and by topographical outrages in the way of crude cuttings and embankments for public works, left bare

of grass and trees, and cut to contours antagonistic to æsthetic considerations.

If one dare in this connection to mention photography, which perhaps I will venture to do, on the risk that there are no artists present, I will say, that the much-wished-and-hoped-for discovery of photographing in natural colors seems to me entirely within the pale of possibility—although I am not going to tell you this evening just how it is to be done. We have already heard rumors in the air of a desideratum of this kind, but a perfect system is still probably afar off—one, I mean, that will be a cheap and simple process, and that will give all the natural colors of the object, pictured with every intermediate shade true to nature.

In regard to the future possibilities of *medical* and *surgical* science, as bearing upon health, the last subject upon my list, we can form but little conception. My own opinion, formed from judging by analogy, is that there are grander possibilities in this field than any of us can realize. Recent improvements in antiseptic surgery go far to show that living bodies can be cut up in almost any way, and that nature seems to have ready a laboratory in which to put them together and repair them again to order. Such facts would seem to lead us to the belief that we are only on the threshold of the wonderful era that is to come. Just now we naturally turn to the brilliant discoveries of Koch, as further establishing a great principle governing the work of conquering our microscopic enemies, which principle was foreshadowed by Jenner, and ratified by Pasteur. Recent experiments also show that remedies purely chemical, applied scientifically, rather than in the empirical way in which drugs have been administered through the past centuries, will hold a leading place in the "curative engineering" of the future.

As in other departments of human knowledge, we can scarcely leave electricity out of the question in this. It is true that the so-called electrical treatment of the past, consisting of sending slight shocks through the muscles, may have benefited patients, perhaps chiefly by imagination;

but new methods of using the electric current are constantly being devised, such as, notably, the conveying of medicinal chemicals through living tissues by a process of electrolysis. Among other future developments we may fairly expect that a correct diagnosis of diseases and injuries will be much aided by some system of brilliantly lighting any part of the body. At all events, the advances in medicine and surgery during the last score of years have been so many and so brilliant, that the more sanguine of us may fairly feel justified in looking to science for the eventual alleviation of all diseases excepting old age itself. And who can say that we may not at some time conquer that?

The timid peep we have attempted to take into the secrets of Nature's Arcanum has been but a cursory one, and probably covers but little of the ground that we seek to investigate. Some of the results we have pictured in our minds may not turn out to be practicable at all. Others perhaps fall far short of what may prove easily attained realities. Many of them seem, to me at least, merely future certainties, which will materialize as fast as the world thinks it needs them—and is willing to pay for them. If even a few of the pictures I have drawn, may happen to serve as hints to discoverers and inventors regarding some of those things which will, in the coming generations, serve to make men happier as well as better, a worthy purpose will have been accomplished. To such investigators I would say: Press forward along every possible line of approach toward the grim fortress in which Dame Nature has intrenched her secrets. Do not fear departures too radical from conventional methods, and do not be afraid of being called "cranks"—only, do not *be* cranks. To avoid this, work within the pale of natural law—as far as it has yet been discovered. Do not try to find out for yourselves things that have already been established and recorded (even in the school text-books on physics) but accept certain facts and principles that a long line of eminent scientists and engineers have made clear. To capitalists, seeking a harvest from the field of applied science, I would

say: Encourage inventors, far more than in the past, but with more discrimination—that you may not purchase will-o'-the-wisps that try to controvert such well-established principles as, for instance, the conservation of energy and the gravitation of matter. To inventors and capitalists, jointly, I would say: Get together and plan your work systematically. The time has come when some organized scheme, for properly using the stored energy latent in your brains, on the one hand, and your money on the other, should be put into practical shape. You all need a clearing house, so to speak, where a general view of your valuable balances can be obtained, after deducting the rubbish due to the brainy man's poverty and crankiness, and the moneyed man's ignorance and credulity. Will one of the "possibilities" we have been talking about be some organization of this kind, taking shape as a splendidly endowed National University of Experimental Science—its faculty a board of mentors, carefully selected from the highest engineering and other technical talent of the land—its students a colony of investigators and inventors, admitted only after passing rigid examinations in the laws of physics and in mechanical sanity?

In concluding this somewhat rambling discourse, let me ask you to lift with me for a moment the veil that shadows the coming generations of our science-endowed race. Methinks I see a smiling land, where the topographical, the agricultural, the architectural, the electrical and, guiding them all, the æsthetic engineers have, unhampered, worked their will. The financial engineer has given them more than moral support, for, by the conservation of its energy—by having learned to avoid waste—the land has waxed rich. I see "things of beauty" everywhere, for we have learned to make for ourselves "joys forever" by allowing no vandal to mar our landscape with an ugly building, or fence, or road. Such of the railways as are above ground are raised above the highways upon artistically designed metal-work, and guide unerringly the feather-weight, rocket-like electric cars that shoot noiselessly by at frequent intervals. Buried wires convey to every farm-house, from distant water-fall or

mine, the vital current that warms and cools and lights them—that cooks their food and runs at will the machinery of the kitchen, the churn in the dairy or the organ and phonograph in the parlor. Without doors this same current has been taught "to plow, to sow, to reap, to mow"—to light the fields at night when needed, as well as to winnow and to thresh. Other wires give telephonic kinship with the world outside, and bring concert, sermon and opera from distant metropolis. On the asphalt highways, underlaid in certain lines, separate from the horse-tracks, with induction plates, glide tricycles and other low carriages of analogous light and elegant construction—their motors running at will when brought over the sunken wire-wound plates.

In our cities, I see like emblems of civilization, urbanized and intensified. Every street and lane delights the eye as a work of art—the buildings not only beautiful in themselves, but forced by some civic power into a co-relation of architectural harmony. Here, in the home of your famous Institute, the guardian spirit of your beloved Franklin has exorcised the tutelary demons of The-coal-smoke and The-cobble-stone, and smiles benignly upon a procession of shining vehicles devoted both to pleasure and to traffic, rolling silently upon their rubber tires over the asphalt pavements of the "New Philadelphia."

THE UTILIZATION OF THE POWER OF NIAGARA FALLS AND NOTES ON ENGINEERING PROGRESS.

BY COLEMAN SELLERS, E.D.

[*Amplified from the stenographic report of an address delivered at the stated meeting of the Franklin Institute, held May 20, 1891.*]

JOS. M. WILSON, President, in the Chair.

DR. SELLERS spoke as follows:

MR. PRESIDENT AND MEMBERS OF THE FRANKLIN INSTITUTE:

It has been many months since I have had an opportunity to address the general meeting of the Franklin Institute, having been called away from the country to attend to the matter about which I will speak this evening.

The Falls of Niagara have always been looked upon as a wonderful work of nature and at the same time as a possible source of water-power beyond anything that exists that we now know of.

Niagara itself seems to be so situated in regard to the population of the United States, as to be a place to which manufacturers might naturally go. As a location affording abundant railroad facilities, close to the line where cheap labor can come to the manufactories, and also on the line of water communication from the Great Lakes themselves, and what is of much importance, near to the great markets.

The drainage area that supplies the water to the Falls of Niagara is something enormous. It can be scarcely realized until you see the figures that have been prepared by the Government of the United States in taking cognizance of the rainfall over one of the largest rainsheds of the country, and from other data as is shown by the following statements compiled from official records of the United States Government and published by the Cataract Construction Company with a map showing the location and the Great Lakes.

"The system of the great fresh water lakes, or inland seas, which drain through the St. Lawrence River into the Atlantic Ocean, extends half-way across the Continent of North America.

"The water surface of these great lakes, with the land sloping into them and contributing to the Falls of Niagara, has a total drainage basin of over 240,000 square miles, equal to more than twice the area of Great Britain and Ireland, about 40,000 square miles more than the total area of France, and more than fifteen times the total area of Switzerland.

"The length of the shore line of these lakes and their connecting rivers is about 5,000 miles.

"The fall of 326 feet between the water levels of Lake Erie and Lake Ontario occurs in the vicinity of Niagara Falls and is distributed as follows:

	Feet.
Five miles of rapids between Lewiston and lower Suspension Bridge,	100
Rapids between Bridge and the Falls,	10
Falls of Niagara,	160
Rapids immediately above the Falls,	50
Upper Niagara River,	6
Total fall,	326

"The Niagara River forms the boundary between Canada and the State of New York. The Falls of Niagara are twenty-three miles below Lake Erie, and fourteen and one-half miles above Lake Ontario. At the Falls the international boundary passes in the middle of the channel that forms the "Horse-shoe Falls," which are 158 feet high, and 2,600 feet wide. The other channel, in the State of New York, forms the "American Falls," which are 169 feet high at the eastern side, and 1,000 feet wide, both falls comprising 3,600 linear feet of water.

"At the Falls the river turns directly at right angle and flows through a gorge, the cliffs of which are 1,100 to 1,200 feet apart, with perpendicular walls rising 210 feet above the water, which has a maximum depth of 189 feet, and a width of from 800 to 900 feet.

"One mile above the Falls the river has a width of 6,000

feet. The extreme limits of variation in the depth of the river above the Falls is three and one-half feet, but these limits are very rarely reached. The ordinary variation is about one foot. Below the Falls the extreme variation reaches fifteen feet. Generally, a variation of one foot above the Falls is followed by a change of level of five feet below the Falls. These slight changes are of short duration and are due mainly to long-continued and violent wind or sudden great accumulations of ice.

"The average discharge of water at the outlet of Lake Erie into the Niagara River is estimated by some authorities at 265,000 cubic feet per second.

"The outflow of the lake basin is about half its rainfall. It has been estimated that if the average discharge of all the lakes passed through a river one mile wide, with a mean velocity of one mile per hour, such a river should have a depth of forty feet from shore to shore.

"The volume of water in the lakes, including Lake Ontario, is about 6,000 cubic miles, of which Lake Superior contains a little less than one-half. An idea of this existing quantity of water is given by the statement that the volume is sufficient, without additional rainfall, to continue the present flow of Niagara Falls for about 100 years, could it be generally exhausted by drainage.

"The flow of water at the Niagara Falls is, for all practical purposes, unlimited, never failing, constant and pure."

There are several reasons why the advantages of Niagara have never been used to any great extent, the chief being engineering difficulties necessitating the expenditure of large sums of money in anticipation of the power developed being taken up. In the beginning of this century it was in the wilds of the backwoods, and people who wished to see the Falls of Niagara had to go on horseback or on foot to reach it.

Perhaps the first traveller who wrote anything of interest regarding the Falls was Father Hennepin, who visited them about 1682, and he probably exaggerated, as his description hardly tallies with what we know of this wonderful work of nature. About seventy years afterwards a Dane visited it

and in an interesting letter to a friend in Philadelphia, which letter was published in the *Gentleman's Magazine*, London, he notes that certain changes had taken place in the great Falls, and it was his comments upon what Father Hennepin had written that gave us our first information that the Falls were wearing back, but it was not until quite recent times that any survey was made to show how rapidly or how slowly the wear was taking place upon the breast of the dam that forms this wonderful fall; now, however, the most careful surveys have been made and monuments placed, so that from this time forward we will know exactly the rate of recession that is taking place.

To bring you to the subject of the evening's discourse, I was in a New England town year before last spending the summer, and I was asked from New York to report upon the cost of transmitting power by electricity as compared to the cost of generating power by steam at any given location.

The gentlemen who had asked this question were those who had been busying themselves with the subject that had first been proposed by Mr. Evershed, one of the surveyors of New York State, who proposed developing the power of Niagara Falls on nearly the same lines that are now being pursued by the Cataract Construction Company for the Niagara Power Company.

I was asked to take up Mr. Evershed's scheme and having examined it very carefully I found that it was feasible, and that if 20,000 horse-power could be disposed of by rental out of the 120,000 horse-power that was talked of being used, a reasonable rental would pay the interest on the investment, not only on the plant that was necessary to develop the power but also of the land that would have to be purchased. On the basis of my report, which was endorsed by other engineers, a company was formed and the money secured to carry out the scheme, Mr. Edward D. Adams, of Messrs. Winslow, Lanier & Co., bankers, of New York, being made the President of the company.

Mr. Adams was in France for a short time last spring, and while there and afterwards in England, he studied the

mode of transmitting power that was being practised in some of the foreign cities. Feeling impressed that it would not be wise for any large amount of money to be expended without knowing exactly what was the best method of proceeding, he sent a cable, asking me to meet him in London.

I met Mr. Adams in London, in May, 1890, and found that he was more enthusiastic than ever in the scheme, but that he was impressed with the idea that as there is not enough land around Niagara to use the power proposed to be developed for the inhabitants, the operatives, and the mill sites, it would be advisable to make the market larger by transmitting the power to a greater distance. With Mr. Adams I visited some parts of Switzerland and Paris, in the latter city to see the plan or system that had been adopted by M. Popp, who, having introduced compressed air as a means of moving the works of the tower and other clocks of Paris, had begun to supply air to and work small motors. The enterprise has increased to such an extent that eventually 120,000 feet of pipe had been laid through the streets of Paris, and more than 10,000 horse-power might be generated by compressed air at his stations to be transmitted to drive engines from forty-five or fifty to 200 horse-power, and down to the smallest dental machines that are used in any establishment, and also operate the cooling chambers where provisions are kept.

In Birmingham, England, extensive works had been erected and power was being successfully transmitted by compressed air. The main thing, however, was to find out what would be the best means of transmitting the power of Niagara Falls to Buffalo, etc., and to get at a knowledge of the exact state of the art of developing water-power as well as transmitting the power. For that purpose it was proposed to interest Sir William Thomson and make him President of a Commission to consider plans to be submitted by selected engineers.

Sir William Thomson many years ago said that the time was not far distant when the city of New York and other distant cities would be lighted from the Falls of Niagara. The city of New York is a great many miles away from Niag-

ara, and I don't know that we are now very much nearer that desirable end than we were at the time he uttered the prophecy; but at all events, there is a great deal more known about transmission of power by electricity to-day than was known yesterday, or the day before. The substantial progress that has been made in this particular branch of transmission is something that is not marked by years of progression, but by daily advance with such rapidity as to astonish the world, apart from the ideal progress in the minds of enthusiastic electricians, which is always greatly in advance of actual results.

It was difficult to find men to act upon a commission with Sir William Thomson to consider the subject, because the majority of those who were noted for scientific pursuits were already retained by one or the other of the various eelctrical companies, or companies for the transmission of power, and it was not very easy to get any who were free and who could act without bias in a commission of this character.

Finally, it was decided to select Col. Th. Turrettini, the Mayor of the City of Geneva, as the representative of Switzerland, because Col. Turrettini was a noted hydraulic engineer, and it was he who had made and supervised the erection of all the improvements on the river Rhone at Geneva, whereby the individually-owned water wheels were swept away from the stream and the power of that river was transferred to all parts of the city, by pipes which convey the water from one central station, from improved pumps, worked by turbine wheels, the water being elevated to reservoirs on the hills and brought down into the town under two different pressures suited to two different classes of use that were to be served. Col. Turrettini had adopted this hydraulic method because the Swiss people were used to hydraulics. They looked upon their mountains and the streams flowing down from the glaciers as their coal mines. They have no coal, but they have water, and water that is running down hill, and water, be it ever so little, if it only runs down hill far enough in a steady stream is a source of power that may be used to drive machinery. During only a few years past,

small streams, that had previously run but a single small flax mill, have been made to drive tens of thousands of spindles by the improved methods of utilizing this water, and the Swiss people found that they had the means of developing a great deal of unused hydraulic power.

It is one thing, however, to develop power and another to get people to use it. America is in a better situation for the use of power than Switzerland, because there are more uses for the manufactures, and more market for the goods, and more reason why the manufactories should exist than in Switzerland. Col. Turrettini, however, would not repeat the hydraulic plant that is now in successful operation in Geneva. In all probability, if he was called to do the work again, electricity would be the agent that he would use for transmission, because at the great falls of Schaffhausen, and other places in Switzerlaand where the power has been transmitted by wire rope to a number of mills, they are now substituting for their much-lauded rope transmission, electrical transmission of power, and claim to be doing it in a paying way.

Near the town of Grenoble, in France, there was a paper mill that was operated by steam. It didn't pay, and it was proposed to take water-power, about five miles off in the mountains. These mountains are inaccessible in winter. During that season it is impossible for any one to pass from the paper mill to where the wheels are placed, and they can only communicate with each other by means of the telephone or telegraph. For nearly two years this paper mill has been operated by the water of a stream in the mountains that has given them the power to run their works without the slightest interruption by any of the great storms that prevail in these mountains. They say they have now become used to it, and are so well satisfied with it that they propose duplicating their machinery to rent power, which they can do profitably at the rate of about $20 per horse-power per annum. At that place they claim fifty-five per cent. efficiency by the continuous current they are using.

To co-operate with Col. Turrettini and Sir William Thomson, by the advice of many who knew him well, Prof.

Mascart, of Paris, the head of the Meteorological Bureau of France and professor in the University of France, was selected because he is known to be well-informed on the possibilities of electricity.

By great good luck, Prof. W. C. Unwin, of the Central Institute of London, Dean of the Faculty of that great school which is intended to teach the sciences to young men under the patronage of the United Guilds of the city of London, was induced to accept the position of Secretary to the Commission, so that the Commission came to be:

Sir William Thomson, President; Coleman Sellers, Professor of Mechanics of the Franklin Institute, as representing the company and the United States; Col. Th. Turrettini, Mayor of Geneva, Switzerland, to represent his country; Prof. E. Mascart, of Paris, to represent France; Prof. W. C. Unwin, Secretary.

The headquarters of the Commission, by the kindness of the Directors of the Central Institute, was established for the time in the Central Institution building in South Kensington, and in that room the many conferences were held and the correspondence conducted that was required in a matter of such great importance to the company interested, and to the scientific world at large.

At early meetings of the Commission held in London, the persons were selected whose advise was deemed of great value and these engineering firms and individuals were asked to submit plans:

(1) Of the generation of the power by turbines or other water motors.

(2) For the transmission of the power so generated to the factories on the land of the company, and then to an area within a two-mile radius from the Central Station. After that to Buffalo and Tonawanda, or to the area contained in a circle within a radius of twenty miles.

Not only were substantial prizes offered, but to all those who would submit plans and estimates in accordance with the specifications, a sum of money was to be paid that would in some degree compensate them all for the labor expended.

The plans and estimates came in on the last day of the

year 1890, but the meeting of the Commission to decide on the plans was not held until the latter part of the month of January, 1891. This meeting lasted one week and was conducted with great care and dignity, mainly in French.

Some of the estimates submitted were remarkable, illustrated by many costly drawings, finished on the highest plane of excellence and accompanied by volumes of valuable information. The whole of the plans were so duplicated that each member of the Commission became possessed of a set of the drawings, specifications and estimates, as also of the written explanations that accompanied them.

All of these schemes were based on what the company has already begun, and which I will briefly explain to you.

The Niagara River above the Falls, flows from the east to the west and at the Falls, the lower gorge into which the water is carried by the two great Falls, the American and the Horse-shoe, runs almost due north towards the west end of Lake Ontario. Between the line of the New York Central Railroad as it enters the town of Niagara, and the river bank, is a strip of land averaging sufficient width to permit the laying out of a manufacturing town as an extension of the town of Niagara, with room sufficient to permit a long canal from the river to run parallel with the railroad, to enter the river below Grass Island with a diverging mouth of sufficient width to, of itself at its lower end, give water at the Central Station to the whole amount required if need be.

Streets are being laid out above Port Dey, where the existing hydraulic canal takes its water, for the location of mill sites, while farther up the river a large area of land, in all about 1,400 acres, will be reserved for dwellings of the operatives in conjunction with other large areas not owned by the Niagara Power Company, but being worked in harmony with it.

A tunnel requiring about 490 square feet of rock excavation is being driven from above Port Dey on the land of the company under the town of Niagara to a few feet below the Upper Suspension Bridge, a total length of 6,700 feet to be extended up stream farther, as required when the mill sites

may be occupied. Only the lower end of the surface canal, as designed to feed the wheels that are to discharge into the tunnel, will be at present built, as from this point all the business will be allowed to grow upon the lines presently to be pointed out to you.

The tunnel will pass under the existing hydraulic canal that feeds the mills, which at present exist in the town of Niagara on the bank below the Falls. This canal has been in operation for about forty years, and begins at Port Dey, at the immediate head of the Upper Rapids of the American Fall; Port Dey taking its name from one who was largely interested in the enterprise and who has been noted for his connection with the manufacture of india-rubber in the United States. The canal passes through a reservation 100 feet wide, but is only 35 feet wide, and carries the water into a forebay parallel with the lower river, whence various factories are being fed. The whole amount of water that this canal will deliver is already exhausted so far as the power it is capable of yielding is concerned, with at present an operating efficiency of about 6,000 horse-power. This power may be increased to double the amount by utilizing all the available fall, but it cannot be increased beyond that without deepening or widening the existing canal.

It may be noted here, that the mills that are fed by this hydraulic canal have been conducted with profit to their owners, on account of the steadiness of the water-power and the many advantages offered by Niagara as a site for manufacturing operations, as well as the great railroad facilities that have been for a long time in existence.

The question has many times been asked, why use a tunnel for a tail-race and place the mill sites above the Falls, when a more natural plan would be a duplication of that already illustrated in the hydraulic canal feeding the existing mills? I might here give a few reasons why it cannot be done. In the first place there is no land at any reasonable price available for manufacturing purposes along the lower river. Public opinion is very much against the further extension of manufactories on the banks of a stream to the detriment of its picturesque features, and for the

preservation of the æsthetic elements of the Falls, large sums of money have already been expended to secure and perpetuate them. It was at a very great expense that the State of New York bought from the owners, the mills that were standing on Bath Island in the Upper American Rapids, and bought the land immediately adjacent to the Falls, and laid out the beautiful park which is now free to the public, and enables all who may wish, to view at their leisure the wonderful cataract. There is a strong feeling against any further erection of manufacturing establishments on that part of the river, and were such an enterprise feasible by reason of land available for the purpose, I would beg you to note that from the head of the upper rapids to the bank of the lower river there is a fall in the ground, leaving less available head at the lower chasm than is represented by the total head between the water above the upper rapids and the water in the lower river, which is about 216 feet, while at the lower gorge it is not quite 200.

Water cannot be carried by canals at nearly so rapid a rate for use in water-wheels as the tail water or waste water that runs away from them can be discharged through a tunnel of rock. For canal purposes, a velocity of not much over three feet per second is the amount that is safe to use, while in an underground tunnel the velocity may be carried, without serious detriment to the rock bed or to brick lining to as great a speed as twenty-five feet per second. Now it is this possible high speed in the tunnel, which does not occupy any space so far as buildings are concerned, but passes under the town through a right of way that has been granted for the purpose, that enables a volume of water to be discharged which if it were carried by canal on the surface of the ground, would require a canal to be perhaps 400 feet wide and from 10 to 15 feet deep, forming of itself quite a a respectable river.

The plan proposed by Mr. Evershed contemplated a number of surface canals entering the land of the company one above the other, at right angles to the river, and passing from the tunnel, which was to extend under the new town. This plan has been changed to the one canal with

lateral branches that I have mentioned. The canal construction will begin at its lower end only, that the company may decide tentatively upon what is the best line of proceeding to obtain the end they have aimed at.

In regard to the possibility of utilizing this power and doing it to the best advantage, the company can proceed at once with certainty as to what will be advisable as a beginning. Changes in modes of manufacturing and transmission are going on so rapidly, and so much information is being received, that it has been decided that a certain amount of power will be sold for local mills that shall control their own wheels and deliver water into this tunnel. This is to satisfy those people who wish to conduct their own manufacturing establishments in the old-fashioned manner.

There will be a central station for the generation, first of about 5,000 horse-power by compressed air, another one of 5,000 horse-power by electricity, with the possible extension of either one of these to the amount of 100,000 horse-power added in units of 2,500 to 5,000 horse-power to either, one by one, in whichever direction proves the most profitable and is called for by manufacturers. The company is anxious to do this work cautiously, economically and thoroughly and to avoid mistakes. With this intent the matter has been placed in the hands of a Board of Engineers, of which I am now the chairman, with Col. Turrettini as foreign consulting engineer, and Mr. John Bogart, the State Engineer of New York, as consultant with me, Mr. Clemens Herschel, the hydraulic engineer of the company, and Mr. Albert H. Porter, the grandson of the one who originally owned Niagara Falls, as the resident engineer of the company at Niagara.*

It was in 1804 that Mr. Porter's ancestor took up the land adjacent to Niagara Falls, and the Falls too, as far as his Government had control over it, from the United States Government. He was virtually the owner of the Falls and the land about it, and his family owned it down to the present time, still holding some of the land, and it was from the

* Since this address was delivered, Mr. George B. Burbank, C.E., has been made resident consulting engineer at Niagara Falls.

Porter family that the State of New York bought the land that has been made into the park, and from them bought the mills that have been erected on Bath Island in the Upper American Rapids.

Niagara offers a wonderful opportunity for a water-power of a stable character, more stable than any river that has been heretofore utilized. The difference of river level from time to time is slight, there is little more than three feet variation at the most in the river above the Falls. Whatever change takes place in the upper river to the extent of a foot, means a change of five feet in the lower river because there the channel is so much narrower and deeper that this vast width of about 6,000 feet above the Falls is forced into a narrow gorge only a few hundred feet wide. It is not known exactly how much water there is going over Niagara Falls. There have been a great many guesses and some computations that are more or less accurate, but they differ so much that doubt is expressed in regard to all of them.

The most careful examination goes to show that the amount of water taken by the Niagara Power Company, if they find people who can use 120,000 horse-power, which means a great many Lowells and Holyokes or a great many of the water-powers of New England put together, will probably affect the depth of water passing over the Falls about one inch and no more. Hardly perceptible when you think that a vessel loaded with timber has gone over the centre of the Horse-shoe Falls seemingly without touching. When you have become familiar with the stream and have learned how to realize its immensity, you will not fear loss of volume of cataract by reason of this little hole in the rock, large as it is in fact, that will be required to take away the water that has developed 120,000 horse-power.

Now 120,000 horse-power used on land serves a large amount of manufacturing industry. It seems to go farther on land than it does at sea, where the steamships that are now trying to eliminate the distance between the shores of England and America require as much as 14,000 horse-power in a single vessel. A few such ships would use up all of this

amount of power, but at sea the whole of the mighty force is expended in driving a screw at the stern of a vessel to force it across the ocean. It is the simplest and crudest form of transmitted motion applied directly to the purpose. To utilize power on the land is a more difficult problem.

Consider, if you will, what we have in Philadelphia, if you will go up towards the Reading Railroad, Broad and Pennsylvania Avenue, and look at the establishment where the wrought-iron car wheels that the Baldwin Locomotive Works have shown you to-night are made, where over 4,000 workmen are gathered in one establishment, that establishment not being on a single city block, but covering five or six city blocks and requiring all its machinery to be put in motion by steam engines with power transmitted by shafting to various parts of this scattered establishment. The 4,000 or 5,000 workmen employed in these buildings require only about 2,500 horse-power of steam to drive the machinery that is giving them employment.

Close by are the works of Wm. Sellers & Co., Incorporated, where 600 men are using about 300 horse-power of steam; in both of these cases there is about two men to each horse-power of power. But what is taking place in these establishments? In that of Wm. Sellers & Co., to which I was attached for more than thirty years, shafting has been made of the most perfect character. There the first efforts were made to manufacture shafting as yards of cloth are made, reducing it to a system that was interchangeable in its parts. What have they learned by this thirty or forty years of work? They have learned that when power is transmitted from a central engine by shafting, seldom more than fifty per cent. of the power created reaches the machines, so great is the friction of the best shafting that can be made, having the best care and with the best lubrication. For small places and short transmission this may be reduced to fifteen per cent., but when extended to a greater distance it eventually comes to fifty per cent. loss, and as the establishment becomes larger the efficiency of transmission diminishes more and more. A line of shafting two miles long could

not, it is estimated, be turned from one end; it would twist itself off before you could turn it.*

In Switzerland, they had the wire rope transmission, and carried the power with much greater efficiency than by shafting for a distance of three miles, but this is being thrown aside for electricity. I have with me papers that have now been sent from Oerlikon, in Switzerland, telling us that they estimate that power may be transmitted for fifteen miles at a cost of less than $60 per horse-power for the actual cost of machinery, etc.

There are men in England who believe that it can be done cheaper than that. I had an opportunity to see many interesting things while away, because the great places that were developing electricity were thrown open to me in a manner that was exceedingly gratifying to me. I saw the operation that is being attempted by Ferranti in London, where he believes that by going to Deptford, on the Thames River, as business men would place a gas works, so he would place his electrical station, where he can get coal cheap, get rid of ashes readily, and obtain water for his condensing engines, etc., and, though the part of London that he is to give electricity to lies at a distance of seven and one-half miles from where the main station is, he aims to transmit electricity that distance underground by concentric cables at 10,000 volts. He had several breakdowns at first, but the last account that I have is that the plant is running smoothly. Mr. Ferranti is a young man, only twenty-six years old, but he is a very venturesome mechanic. He is putting up engines of 10,000 horse-power very like such as would be used on steamships. Upon the shaft of the engine he is arranging a massive fly-wheel, which is in fact the revolving armature of his dynamo, this armature being forty-five feet in diameter. He believes in steam-power being developed in large quantities by large engines, but electricity in small units. The electrical machines that he strings around the rim of this fly-wheel he conceives can be as well placed there as strung in a line on the floor, and can be coupled up as he

* See *Kapp's Electric Transmission of Energy*, p. 233.

may require for his purpose. He has four lines of concentric cables to carry the electricity to Grosvenor Square section of London, to a station where the voltage is reduced to perhaps 2,000 for local distribution, and then by other transformers into the houses of the district. London is so vast a city that units of power for lighting that would be out of proportion in smaller towns may be none too large for such a population for the lighting of a city where over 5,000,000 inhabitants are calling for light sometimes in winter and in their dense fogs, for what with us would be day as well as during their long nights.

I understand that Ferranti has gotten through the difficulties he had to contend with through the acts of Parliament and the post-office regulations in London, because it has been found that the current in his concentric cables does not interfere with the underground telephone and telegraph wires, so London is now being lighted by this plan to a certain extent in the Grosvenor district, the part of London that I was living in.

As to the safety of this kind of transmission, I understood Lord Crawford, who was the chairman of the company, at one time to say that a man had held a chisel in his hand and allowed another man to drive that chisel by hammers through the concentric cable when 10,000 volts were being transmitted as was thought, but when in reality 15,000 volts were passing, and he suffered no damage, though he was standing with damp feet upon an iron plate upon which the naked cable lay.

I was invited to see the same experiment tried again, but I did not accept the invitation, knowing that it is perfectly safe if the chisel strikes the outer and inner conductors of copper that form the cable, the current is only short circuited, the safety fuses go off and the chisel can be so held without damage to the operator, but if a small portion of the outside copper casing be cut away and then an attempt made to cut the inner coil of copper, the operator would not know what had happened, so quickly would he fall.

In Switzerland by means of the oil transformers adopted by Mr. Brown of Oerlikon, who has experimented with

transmission by electricity at 30,000 volts, having a sparking distance of about an inch in the air, and by means of the so-called rotary alternating currents, they are about bringing to Oerlikon the power of a waterfall a number of miles from that place and driving their whole establishment by electricity and not by steam and shafting transmission.

At the time that I visited the Oerlikon works they were already taking down line shafting and placing motors in various parts of the establishment nearest to the machinery to be driven, and though they were as yet generating their electricity by means of steam engines, they considered this method of transmission much more economical than shafting, and they proposed to extend it throughout their entire works.

I went to Rome to see the plant there and that which is being constructed at Tivoli. The power will be brought from Tivoli to Porte a Pia at Rome by naked overhead wires at 5,000 volts, with the expectation of having at Porte a Pia about 4,500 volts to be lowered to 2,000 to enter the city of Rome by underground concentric cables, and then lowered by other transformers to enter the houses.

I was agreeably surprised when I went to Rome to see so perfect a plant as they have established there under the auspices of Ganz & Co., one of the firms that submitted plans to the Niagara International Commission. They use the alternating current and the three-wire system, and at present, so far as I can see, the alternating current seems to come to the fore on account of the ease with which it can be transmitted long distances, the voltage raised and lowered by means of transformers, not involving such great cost of cables as is required by the continuous current. At Rome, arc and incandescent lamps are operated conjointly by the same three wires.

Prof. George Forbes, was one of the first men of science to acknowledge the fact that the future of electricity looked very much as if the alternating current would be the most profitable one for transmission of power a long distance. I went with him to see the Mordey alternater at work in London, where they operated one of

their generators for us as a motor, giving it work to do to the extent of fifty per cent. more than its calculated capacity without its showing the least fatigue, and after half a day's work not even being warm. There was no trouble in any way with it and it illustrated the beautiful condition of being constant in its speed, no matter whether a load was taken off or put on, for when the driving power is constant and uniform in its speed, the motor driven by it and in step with it is constant, being in no way affected by change of load.

Speaking of Prof. George Forbes, so well known as a scientific electrical engineer, I was much impressed by his bold stand in favor of the alternating current, and his command of the subject as an educated engineer, in presenting his plan of utilizing the power of Niagara. Looking back to the meeting held in London and my opportunity to meet men noted in scientific engineering, some among them seem to tower mentally over others, and one can readily fee. that such men are masters.

In Rome, where the experiment was first demonstrated practically of running alternating current dynamos parallel, coupled electrically only, and not by mechanical coupling, the engineer of the Roman works, Dr. Mengarini, has adopted as a unit 600 horse-power for the Roman plant where it is driven by steam made from the coke of the gas works, but at Tivoli the units of power will be 350 horse-power each.

In Rome, where the Cæsars built their great circus, and on the very stones placed by Cæsar, stands the foundation of the engines that now furnish light by gas and electricity to the city of Rome. The gas company of Rome concluded to create electricity by steam only as far as the coke as a by-product of their gas works would permit them to do it, but it is for additional supply they go fifteen miles away to Tivoli to take advantage of the water-power at that place and bring thence to Rome electricity at a high voltage. The beautiful old villas that stood along the olive covered heights of Tivoli have been faced by a grand aqueduct that brings the water collected from streams to one huge build-

ing, where the first fall of the water is 160 feet to the first set of wheels, where in one room six wheels will give motion to the six dynamos, with three other dynamos to give the constant current for the magnetization of the six main dynamos, and after that when they wish to extend their plant, they can drop 160 feet more to other wheels and even then they will not be at the bottom of this great building.

The work of the Cataract Construction Company at Niagara is now being pushed as rapidly as it can be, and it is gratifying to know that people are already looking forward to Niagara as a home. There has been leased already to one single firm for the purpose of paper mills and pulp works, 3,000 horse-power, and they will begin the erection of their works at once.

You may wonder why compressed air is thought of at all for transmission, as you have known in America that it has been thought to be a very wasteful manner of transmitting power, but the recent improvements that have been made in compressors have very much changed the condition of that mode of transmission and the fact that so much gain is possible by reheating the air indicates a cheap power which can be transmitted long distances, with economy, dispensing with long lines of shafting.

I myself think that electricity is the most perfect and economical method of transmitting power, but people are not ready to set aside their steam engines and substitute electric motors for them at once. They will take air that can be given to them in place of steam when they find that a handful of coal will very much increase the power of that air at their works and enable air motors to be used close to the machines to be driven.

I was in one establishment at Birminghan where there were many houses united together that had been added one after another to form an establishment for making bedsteads. Formerly power was transmitted to each by shafting from a central engine—a very wasteful process—but when compressed air was put into Birmingham by Mr. Sturgeon and Prof. Lupton, this bedstead factory took this compressed air from the station, passed it through a coil

boiler over an ordinary fire made of coke that is no larger than would be required to heat an ordinary dwelling house, the fire tended by a boy. The air passing through this boiler is carried to engines and these engines run without any attention whatever. The engines are warm—the air is exhausted at a temperature a little above that of the outside air, not down to the freezing point, the pressure of air is at most only sixty or seventy pounds and they have something to work with that is like the steam used formerly to drive steam engines. Cupolas are driven by a jet of high-pressure air in a jet blast; so are blacksmith forges in the same way, and so on all the different parts of the establishment; everything is done by compressed air and with absolute satisfaction.

In Paris it became popular at once because it is difficult to introduce steam into that city. Coal is very costly, the municipal regulations are against the use of steam; they are afraid of it. They are not afraid of compressed air. Having laid the pipes down for one purpose (that of operating clocks) it was an easy step to introduce it for other purposes. The establishment at which Mr. Popp is the head has more to do than at Birmingham. He is doing some part of the city lighting by electricity. Why doesn't he transmit the power by electricity? All I can say is that he don't do it. From his main station he transmits the compressed air to engines that drive the dynamos to light other parts of Paris. Mr. Popp sent me a very interesting communication a few days ago, saying that the government of Paris was very much concerned about stocking the city of Paris in case of another siege, and a large sum of money was voted by the government to have experiments tried in the various methods of keeping provisions in cooling chambers. Mr. Popp told them it wasn't worth while to be uneasy about that, and he invited the Secretary of War and others to the stations I had visited in Paris, where there may be about 10,000 horse-power generating compressed air. He said that by driving one-half of this machinery itself by compressed air instead of by steam, and building temporarily near this station cooling chambers to contain

the provision, that at once cold air from the exhaust could be thrown into them to lower the temperature below the freezing point, and give them sufficient cooling capacity to carry the provisions for at least a six-months' siege of Paris, if not longer, without any great cost. The very machinery that had been used to give power in peace, could in a state of siege when power wouldn't be wanted, at once be turned into another use, that of furnishing the means of keeping the provisions that were required to feed the population locked in by an invading army.

This use of compressed air for cooling purposes is an important item in favor of its use in large cities, and it is being considered by some of the other great cities of Europe. Berlin and other cities are now perfecting their organization for the erection of compressed-air establishments to supply power as it is supplied by water in London, by compressed air in Paris and Birmingham, and in a slight degree by steam in New York, but in very few places by electricity.

Compressed air has been quite successfully used on some of the tramways. One tramway that I visited at Chester, England, is an example of such a system of low-pressure compressed air. It is necessary to carry only fifty cubic feet of compressed air in each tram-car, as they can recharge without stopping. Whenever they want to take up a charge of compressed air they drop a plow blade which lifts up a cover plate with grooves on its lower side, the groove forms a guide connecting the car attachment with the device for letting in the compressed air. I have seen the tram-cars so arranged running at full speed, open the plate, take the charge, and shut the plate without any interruption. In Philadelphia the roads could be supplied with that system admirably, because it does not follow that the power must be transmitted over every foot of the line as it is by the trolley system of electricity, but each car carries the power from station to station compressed within its reservoirs and the car is not a helpless dead machine when off the track, but carries its power with it.

The development of compressed air at Niagara, you can

understand, merits consideration when 50,000 horse-power, we are told on good authority, can be carried twenty miles distant through two pipes, each 26 inches in diameter, with a certainty that by increasing the pressure for the time being, one pipe alone might carry the entire amount while the other one would be under repair, so it is not so very costly, after all, to carry power by means of it, and people can use what they are accustomed to, an elastic gas similar to steam so that large and small steam engines now in existence can be operated as if by steam. This is what is inducing the company to be prepared to develop its work on the three lines: one of compressed air, one of electricity, and the other of developing it on the ground by separate wheels, but I would like all of you to think of this subject as mechanics, and to think of what is now being done in the present method of transmission, and how rapidly people's eyes are being opened to the necessity of some other mode of transmitting power. Electrical motors are now used to work 100-ton travelling cranes and in comparison with square shaft driving are considered more economical. Electricity, too, is used to drive swing cranes and drilling machines. It lends itself to division in a manner that is wonderful in the extreme and permits better results than anything that can be conceived of, the only doubt is that the progress of invention is going on so rapidly that we are almost at a loss to know what particular line should be pursued in preference to others, and therefore the Cataract Construction Company proposes to proceed tentatively.

Before I quit the subject of compressed air, I will tell you of a man in England, Mr. J. Pearsall, who was one of those who presented plans to the Commission, and who says that the best way to generate the power by compressed air is to do it by a hydraulic ram. Pearsall is no visionary. He has already accomplished the result on a small scale. There is running in Pennsylvania one of his machines, and he has adopted the principle of the hydraulic ram with which you are all familiar and in place of the valve closed with a slam by the current he has introduced a set of valves driven by a separate power, thus doing away with the weak point of the

ram system and made it perfectly and entirely feasible to compress air by the water, not by the weight of the fluid columns only, but by the impact of the water. Having obtained power by velocity, by properly operated valves he cushions the stream on the air, compressing it and driving it into the distributing mains.

He has shown on a small scale that this can be done much more cheaply than by creating the power by water wheels and compressing the air by costly compressive machinery, so that this may be looked at as one of the modes that will render the use of compressed air cheaper than electricity.

I have given you a brief outline of what is being done at Niagara, and I would like to tell you of many more interesting things seen in England, but I must call your attention to one difference of methods that prevails between engineers in Europe and in this country.

I found, go where I would on the Continent of Europe and in England, that engineers were using the ordinary carpenter's slide rule, usually the kind called the Gravet slide-rule, for doing all their calculating, while here few know anything about it at all. I began to inquire into this while in London, and found that they have some remarkable instruments for this purpose that are convenient to carry and useful in every way. With these instruments calculations are made without pen or pencil far more readily than you could possibly do them by the old-fashioned method. A celebrated engineer said that everybody should learn to calculate by the rules of arithmetic, but as soon as they got hold of a machine to do the work for them, they had better forget the rules learned at school. It would be well for young engineers to become accustomed to using these instruments, for it is easier to learn to use them while young than later in life.

I have in my pocket (producing the Boucher's calculator) a little instrument that looks like a watch, a calculating machine where the scales of the slide-rule are in a circle; one side of the instrument gives square roots and the other cubes, the logarithms and sines, etc. If now, you want to know the power of a certain engine, knowing its speed,

mean effective pressure and dimensions, this little instrument will resolve the simple equation of

$$\frac{\text{area of piston} \times \text{mean pressure} \times \text{feet per minute}}{33{,}000}$$

by successive setting of the dial or pointer with an answer at the fixed index. It is done at once without any calculation, without any trouble, and without the possibility of a mistake.

There have been many forms of these instruments devised. In one the scale of logarithms is wound around a cylinder; such is the Fuller spiral calculator, representing an ordinary straight slide-rule eighty-two feet long and capable of being read to five or six figures.

If it has been worth while for me, at my time of life, to learn the use of these instruments, it is surely worth the time of you younger men, for I can assure you that things like this are not picked up as quickly after you have passed fifty as in earlier life, and it is well worth the effort required to master them.

I hope what I have said has been of interest to you, and thank you for your earnest attention.

[At the conclusion of his remarks, the thanks of the meeting were unanimously voted to the speaker.]

NEW ALLOYS AND THEIR ENGINEERING APPLICATIONS.

BY F. LYNWOOD GARRISON.

[*A lecture delivered before the Franklin Institute, January 30, 1890, and February 6, 1891.*]

[*Continued from vol. cxxxi, p. 460.*]

Dr. Dudley writes, "We tested the test bar and found 78,500 tensile strength with fifteen per cent. elongation in two inches, and four and one-half per cent. in eight inches. This high tensile strength can only be obtained when the metal is manipulated. Such high results could hardly be expected with the cast metal.

The following analysis of Tobin bronze,* made for me by Mr. James S. de Benneville, agrees very closely with the rolled test bar analyzed by Dr. Dudley:

Copper,	61·203
Zinc,	37·440
Tin,	0·906
Iron,	0·180
Lead,	0·359
	100·088

The alloy is, therefore, practically a brass. It is a well-known fact (as I have already observed in the case of sterro or delta metal) that the presence of a small amount of iron in a copper-zinc alloy has a tendency to increase its strength and ductility, while the lead present tends to make it softer and more fusible.

The Ansonia Brass and Copper Company, who are, I understand, the sole manufacturers of Tobin bronze, claim to obtain 79,600 pounds per square inch tensile strength,† an elastic limit of 54,257 pounds per square inch,‡ and from

* Patented by John A. Tobin, Engineer Corps, U.S.N.

† Tests made by Fairbanks.

‡ Tests made by Prof. J. E. Denton.

twelve to seventeen per cent. elongation with best rolled one-inch bars.

Tobin bronze, according to the inventor's claims, can be forged and stamped at a red heat as readily as steel. Bolts and nuts can be forged from it by hand or by machinery, when cold drawn. Its increased density and high elastic limit, and the facility with which it can be upset, while hot, make it well adapted for special purposes. In forging Tobin bronze it is stated* that particular care must be taken to work it only at a cherry-red heat, and that it should not be worked at a black heat.

Tobin Bronze.—This alloy is practically a sterro or delta metal with the addition of a small amount of lead, which tends to render copper softer and more ductile.

The following analyses of Tobin bronze was sent me by courtesy of Dr. Chas. B. Dudley, of Altoona, Pa.:†

	Pig Metal. *Per Cent.*	*Test Bar (Rolled).* *Per Cent.*
Copper,	59·00	61·20
Zinc,	38·40	37·14
Tin,	2·16	0·90
Iron,	0·11	0·18
Lead,	0·31	0·35

Copper Alloys containing Phosphorus.—Under this head we have three alloys, which have become of any prominence for engineering purposes, viz: phosphor bronze, deoxidized bronze and the so-called Eureka tempered copper.

Phosphor Bronze.—In the year 1868, Messrs. Montefiore & Künzel, of Liège, Belgium, found, by adding small proportions of phosphorus or "phosphoret of tin or copper" to copper, the oxides of that metal, nearly always present as an impurity, were deoxidized to a greater or less extent and the copper much improved in strength and ductility, the grain of the fracture became firm, the color brighter, and a greater fluidity attained.‡

Combinations of phosphorus with copper, and with tin,

* *Ansonia Brass and Copper Company Catalogue*, p. 6.

† Private communication, January 23, 1891.

‡ *Journal of the Society of Arts*, May 4, 1877, pp. 551, 552.

have long been known to chemists, but Dr. Künzel was the first to employ the same for the purposes I have stated.

Perhaps about the best method of making phosphor bronze is to line the crucible with a mixture of eighteen parts bone-ash, fourteen parts sand, and four parts charcoal: the whole ground up with gum-water and the inner surface of the crucible spread with it. Granulated copper then being introduced, covered with a layer of the mixture and subjected to fusion.

At a temperature sufficient to melt the copper, the silica decomposes the bone-ash [$Ca_3(PO_4)_2$], the base of which (calcium) is removed, thus freeing the phosphorus, which reacts on the cuprous oxide in the fused copper, deoxidizing and purifying it. The products of the reaction rise to the surface, form a slag which can be tapped off.

According to Kirkaldy, phosphor bronze produced the following results by physical tests.*

	Elastic Limits. Pounds per Square Inch.	*Tensile Strength. Pounds per Square Inch.*	*Elongation. Per Cent.*
Cast,	23,800	52,625	8·40
Cast,	24,700	46,100	1·50
Cast,	16,100	44,448	33·40

DRAWN METAL (*Phosphor Bronze*).

TENSILE STRENGTH.		TWISTS IN 5 INCHES.		
Wire as Drawn. Pounds per Square Inch.	Annealed. Pounds per Square Inch.	Wire as Drawn.	Annealed.	Elongation. Per Cent.
108,759	49,350	6·7	89	37·5
120,957	47,787	22·3	52	34·1
120,950	53,381	13·0	124	42·4
139,141	54,111	17·3	53	44·9
159,515	58,853	13·3	66	46·6
151,119	64,569	15·8	60	42·8

Samples of No. 2 alloy supplied by the Phosphor Bronze Company (London), and recommended for propellers, when tested by Kirkaldy, gave ultimate tensile strength

* *Journal of the Society of Arts*, May 4, 1877, p. 552.

of 35,392 pounds per square inch, with seventeen and one-half per cent. elongation.*

In some of Dr. Chas. B. Dudley's recent investigations on the wearing properties of metals, it was found that phosphor-bronze bearing metal of the average composition 79·70 per cent. copper, ten per cent. tin, 9·50 per cent. lead, and about 0·80 per cent. phosphorus, gave the following results :†

COPPER-TIN *versus* PHOSPHOR BRONZE.

	Composition Copper-tin. Per Cent.	*Composition Phosphor Bronze. Per Cent.*
Copper,	87·50	79·70
Tin,	12·50	10·00
Lead,	none	9·50
Phosphorus,	none	0·80

Wear.—First experiment, copper-tin bronze wore forty-eight per cent. faster than phosphor bronze; second experiment, copper-tin bronze wore fifty-three per cent. faster than phosphor bronze; third experiment, copper-tin bronze wore forty-seven per cent. faster than phosphor bronze.

ARSENIC BRONZE *versus* PHOSPHOR BRONZE—FIRST EXPERIMENT.

	Composition Arsenic Bronze. Per Cent.	*Composition Phosphor Bronze. Per Cent.*
Copper,	89·20	79·70
Tin,	10·00	10·00
Lead,	none	9·50
Phosphorus,	none	0·80
Arsenic,	0·80	none

Wear.—Arsenic bronze wore forty-two per cent. faster than phosphor bronze.

ARSENIC BRONZE *versus* PHOSPHOR BRONZE—SECOND EXPERIMENT.

	Composition Arsenic Bronze. Per Cent.	*Composition Phosphor Bronze Per Cent.*
Copper,	89·20	79·70
Tin,	10 00	10·00
Lead,	7·00	9·50
Phosphorus,	none	0·80
Arsenic,	0·80	none

Wear.—Arsenic bronze wore fifteen per cent. faster than phosphor bronze.

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* *Trans. of the Inst. of Naval Architects*, 1888, p. 370.

† *Journal of the Iron and Steel Institute*, No. 11, 1890, pp. 216, 263.

ARSENIC BRONZE *versus* PHOSPHOR BRONZE—THIRD EXPERIMENT.

	Composition Arsenic Bronze. Per Cent.	*Composition Phosphor Bronze. Per Cent.*
Copper,	79·70	79·70
Tin,	10·00	10·00
Lead,	9·50	9·50
Phosphorus,	none	0·80
Arsenic,	0·80	none

Wear.—Arsenic bronze wore one per cent. faster than phosphor bronze.

DAMASCUS BRONZE *versus* PHOSPHOR BRONZE.

	Composition Damascus Bronze. Per Cent.	*Composition Phosphor Bronze. Per Cent.*
Copper,	77·00	79·70
Tin,	10·50	10·00
Lead,	12·50	9·50
Phosphorus,	none	0·80

Wear.—First experiment, damascus bronze wore eight per cent. slower than phosphor bronze; second experiment, damascus bronze wore 7·30 per cent. slower than phosphor bronze.

	Composition Alloy "B." Per Cent.	*Composition Phosphor Bronze Per Cent.*
Copper,	77·00	79·70
Tin,	8·00	10·00
Lead,	15·00	9·50
Phosphorus,	none	0·80

If we interpret the above results correctly, they indicate: First, that copper tin wears nearly fifty per cent. faster than standard phosphor bronze; second, that arsenic bronze, containing no lead wears about forty-two per cent. faster than phosphor bronze; third, that arsenic bronze containing seven per cent. of lead wears less rapidly, the exact figure being fifteen per cent. faster than phosphor bronze; fourth, that arsenic bronze containing the same amount of lead as phosphor bronze, wears but slightly faster, the figure being one per cent.; fifth, that damascus bronze containing as high as 12·50 per cent. of lead wears from seven to eight per cent. slower than phosphor bronze; and, sixth, that the experimental alloy "B," containing less tin and more lead than any of the other alloys experimented with (the figures being eight per cent. of tin and fifteen per cent. of lead, instead of ten per cent. of tin, and 9·50

per cent. of lead, as is characteristic of phosphor bronze) wears 13·50 per cent. slower than phosphor bronze.

Another, and perhaps the most general, method of making phosphor bronze, is by the single addition of *phosphor tin*. Phosphor tin is made by heating three parts of anhydrous phosphoric acid with one part carbon and six of tin. The resulting alloy has a silvery white crystalline appearance, which dissolves in hydrochloric acid with the generation of sulphuretted hydrogen. According to Pelletier, this alloy appears to possess the composition of Sn_3P_2; it melts at 370° C.*

In Brannt's metallic alloys it is stated "that, according to the purpose for which the bronze is to be used, from 0·25 to 2·5 per cent. of phosphorus is added."† He gives the following analyses of different kinds of phosphor bronze:

	I.	*II.*	*III.*
Copper,	90·34	90·86	94·71
Tin,	8·90	8·56	4·39
Phosphorus,	0·76	0·196	0·053

It will be observed that the amount of the element phosphorus present—which is supposed to give the alloy its distinction—is extremely small. This, however, is only what might be expected if the supposed *rôle* the phosphorus plays in the manufacture of the alloy is the correct one.

It will be noted that the analysis by Dr. Dudley, which I have quoted, indicates the presence of 9·5 per cent. lead. Dr. Dudley states that this analysis is an average one, and will not vary more than one or two per cent. in the amount of the constituents from hundreds of thousands of pounds which have been received and used by the Pennsylvania Railroad Company.‡

Besides, as a bearing metal, phosphor bronze is useful for a large number of purposes, such as pump cylinders, hydraulic presses, piston rings, eccentric rings, etc., also for propeller blades, bells, wire, screws, gun-powder machinery,

* See *Dingler's Journal*, 225, p. 514; and 221, p. 188. *Zeitschrift für das Berg-, Hütten- und Salinenwesen im Preussischen, Staate*, 1876, s. 6.

† Page 208.

‡ Private communication

tools, etc. Blast furnaces are sometimes provided with phosphor-bronze tuyeres, which which are said to give most satisfactory results.

Deoxidized Bronze.—This alloy is manufactured by the Deoxidized Metal Company, of Bridgeport, Conn. It resembles phosphor bronze somewhat in composition and also delta metal, in containing zinc and iron. The following analysis gives its average composition:*

Copper,	82·67
Tin,	12·40
Zinc,	3·23
Lead,	2·14
Iron,	0·10
Silver,	0·07
Phosphorus,	0·005
	100·615

It seems probable some deoxidizing flux containing phosphorus, similar to that used in the manufacture of phosphor bronze, is made use of in the manufacture of this alloy. Deoxidized bronze is largely used for wood-pulp digesters, as it is found to resist the action of sodium hyposulphite and sulphurous acid remarkably well. The above-mentioned company have been quite successful in making these digesters, which are usually cast in annular sections (weighing about 4,000 pounds each) and bolted together through their flanges. The company claim this alloy to be superior to any other bronze for blast furnace tuyeres. This claim, however, I believe to be unsubstantiated, as I cannot see that it is any better for this purpose than several other similar alloys.

Deoxidized bronze wire has a tensile strength in the neighborhood of 150,000 pounds per square inch. The deoxidized copper wire made by this company, has a tensile strength of 70,000 pounds per square inch; and the deoxidized copper sheets, a tensile strength of from 30,000 to 50,000 pounds per square inch.

Eureka Tempered Copper.—The application of the term

* Analyses were made by Mr. Jas. S. de Benneville in Dr. F. A. Genth's laboratory.

tempered, as generally understood, to this product, is a misnomer. The material is not in any sense tempered or unusually hardened, it is practically pure copper, which by some treatment* has been successfully cast into small and rather difficult shapes.†

The following analysis by Dr. F. A. Genth, of Philadelphia, of the Lake Superior pig copper from which the castings were made, and the tested castings themselves, show the composition of the castings to have been but very slightly affected by the so-called hardening and tempering treatment.‡

	Pig Copper. Per Cent.
Silver,	0·096
Copper,	99 890
Tin,	trace
Lead,	trace
Iron,	0·056
	100·042

	(1) *Not Tempered. Per Cent.*	(2) *Tempered. Per Cent.*
Silver,	0·026	0·025
Copper,	99·930	99·981
Tin,	none	none
Zinc,	none	none
Iron,	0·082	0·088
Aluminum,	none	none
Arsenic,	0·046	0·042
Phosphorus,	0·017	0·018
	100·101	100·154

It would seem from the analysis that during the treatment arsenic and phosphorus were used in some way, probably as a deoxidizing flux, the chemical reactions taking place being similar to those which take place in the manufacturing of all deoxidized alloys.

* The process is not patented and consequently we can only guess at what it may be.

† The use of the word *difficult* here is relative, as copper castings are rather unusual and are generally supposed to be difficult to make.

‡ *Journal of the Franklin Institute*, December, 1890, p. 418.

The treatment does not appear to affect the physical properties to any extent, the "untempered" cast material of a section ·6493 square inch gave elastic limit 10,080 pounds per square inch, tensile strength 24,410 pounds per square inch, elongation 22·5 per cent.; "tempered" cast material, elastic limit 11,460, tensile strength 25,800, elongation 18·0 per cent.

When rolled on section of ·465 square inch, elastic limit 27,000 pounds per square inch, tensile strength 61,290 pounds per square inch, elongation 4·3 per cent. in six inches.

Compression test on section ·935 x ·938 x 1 inch high was, strain 54,040 pounds per square inch, limit of elasticity 14,820 pounds per square inch, compression 0·28 inches or twenty-eight per cent. On section ·935 x ·939 x 1 inch high, strain 51,600 pounds per square inch, limit of elasticity 15,940 pounds per square inch, compression 0·276 inches, or 27·9 per cent.*

Compression test on a section 1 x 1 x 1 inch of Lake Superior pig copper (untreated or "untempered") was, strain 50,000 pounds per square inch, compression 0·21 inches or twenty-one per cent.

It would seem from this that the untreated pig copper actually withstood the compression strain slightly better than the treated material.

This material (so-called "tempered copper"), however, seems to be particularly good for the following purposes: For bearings on coal-mining machinery it lasts much longer than any other metal before used; that it outlasts from three to four times the old style of commutator copper bars or brushes; very satisfactory for brasses on engine rods; bearings on dynamos run very cool and require but little lubrication; gives entire satisfaction on the bearings of threshing engines; in wrist-pan boxes and in cross-head; as a step in gauge lathe, between end of spindle and set-screw, is superior to hardened steel, brass, rawhide or wood, all of which were previously tried; very uniform in hardness and

* *Journal of the Franklin Institute*, December, 1890, p. 420.

remarkably free from blow-holes; gave good results as a driving pinion in gear work; stood up well as armature bearing in street-car motors (a trying test), in small bearings, where the brass bearings would not last over sixty days the tempered copper has been nearly in a year, and is apparently in as good a condition as when first put in.*

Silicon Bronze.—This alloy appears to have been invented about the year 1881, by M. Weiller, of Angouleme.† In experimenting with phosphor bronze wire for telegraphic and telephonic use he found its conductivity was insufficient for telegraphic purposes, so he devised the alloy now called silicon bronze.

The silicon-copper compound, from which the silicon bronze is produced, is made by melting, in a graphite crucible, certain amount of copper with a mixture of fluor-silicate of potassium, produced glass, chloride of soda, carbonate of soda and choride of calcium. It is claimed the silicon and sodium in this mixture absorb all the oxides present in the mass.‡

The action of the silicon on the copper is similar to that of phosphorus. It acts as deoxidizer and, the silica formed being an acid, is a valuable flux for any metallic oxides remaining unreduced. Wire made from this alloy is said to have the same resistance to rupture as phosphor-bronze wire, but with a much higher degree of electric conductivity. According to Preece, phosphorus has a most injurious influence on the electrical conductivity of bronze, and that silicon bronze is far superior.§ It also seems that, although wires made from this alloy are very much lighter than ordinary wires, they are of equal strength.

According to E. Van der Ven,‖ phosphor bronze has about thirty per cent., silicon bronze seventy per cent., and steel ten and one-half per cent. of the electrical conductivity of copper.

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* *Journal of the Franklin Institute*, December, 1890, p. 422.

† *Hiorn's Mixed Metals*, p. 199.

‡ See British Patent, 1485, 1877.

§ *Hiorn's Mixed Metals*, p. 199.

‖ *Musée Teyler and Electrotch. Zeitsch.*, 1883.

The manufacture of silicon bronze has greatly improved since its introduction; the latest kinds, while perhaps somewhat less in conductivity, have a greater strength, which allows the wire to be more tightly stretched with greater spans. Such wire appears to be particularly efficient when subjected to strains caused by snow and ice accumulations.

IRON ALLOYS.

When metallic iron is combined or, I might say, alloyed with various proportions of the element carbon, we have the ordinary varieties of iron and steel, the purest being wrought iron, containing about ·015 per cent. carbon, then steel with from 0·15 to 1·5 per cent. and cast iron with upwards of 1·5 per cent. There are, of course, numerous intermediate grades whose properties, in a general way, may be said to depend upon the varying proportions of carbon present. There are other elements nearly always present, which to a greater or less degree affect the properties of the metal.

The relations of the carbon, more particularly, and also the other elements present in the iron, bears upon the properties, mode of treatment, etc., of the metal belongs more particularly to the metallurgy of iron proper. It is my intention in this lecture to confine myself to a class of compounds (alloys) which have of late attracted much attention and may be considered essentially new. I refer to the combinations of iron with such elements as aluminum, chromium, copper, manganese, nickel, silicon and tungsten; these alloys are termed steels with a prefix of the name of the predominating and particular element present.

These alloys constitute about the most difficult class with which we have to deal. The influence of some of the elements above-mentioned is exceeding subtle in many cases, and while numerous experiments have been made with most of these steels few or none have been attempted with their combinations, as for instance a steel composed of a mixture of nickel steel and copper steel.

One thing must not be overlooked in considering alloys of steel, that whereas frequently admirable results are

obtained, in some respects the material is practically worthless on account of its unworkability in the ordinary operations of the machine shop, such, for instance, as some of the grades of manganese steel.

One of the most serious disadvantages, connected with the use of mild steel for ship-building purposes, is its greater liability to corrode in salt water than iron. This is due to the usually greater purity of mild steel. In several of the new steel alloys, more particularly nickel steel, this defect is overcome, as in them we have a particularly homogeneous material of even greater strength than mild steel and much less corrodible by the action of salt water.

Some of these alloys seem to be particularly well adapted for rivets; the importance of this fact cannot be over-estimated when we consider that the limit of strength of steel suited for ship-building, boilers and other riveted structures is not so much determined by the quality of the steel that might be used, as by the quality of the rivet steel used in combining plates of high tensile strength. The Landone Steel Company some years ago found, by the results of many experiments, that the limit of strength of steel best suited for ship-building was not determined so much by the quality of the steel plates as by the quality of the steel rivets used.

I should mention that none of the tables in the following text are original, having been derived largely from Howe's work on steel and from other sources, such as Hadfield's papers, etc.

[*To be continued.*]

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, June 16, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 16, 1891

Dr. W. H. WAHL, President, in the chair.

Ten members present.

ominations:

Dr. W. P. Mason, Troy, N. Y.

Oliver Hough, 325 South Sixteenth Street.

Owing to the absence of the election committee, a motion was made by Mr. Bower to suspend the rules, so as to permit of the election of the above gentlemen by the Section. Carried.

Dr. Mason and Mr. Hough were then elected.

Mr. Garrison's paper was postponed until further notice.

Dr. Koenig read an interesting paper on "A Remarkable Boiler Scale from Galveston, Tex." Referred for publication.

Mr. Ives gave some illustrations of the results he has obtained in color photography.

Prof. Trimble presented a paper on "The Tannin of the Chestnut Wood." Referred for publication.

Dr. Wahl exhibited a new incandescent gas lamp, similar in structure to the Welsbach incandescent lamp, but said to possess more lasting properties.

Adjourned. LEE K. FRANKEL, *Secretary pro tem.*

On the Percentage of Iodine absorbed by Lard Oil, by the Hübl Method.

By Reuben Haines.

[*Read at the stated meeting of the Section, held March 17, 1891.*]

The examination of lard oil for adulterations is of importance not only from an economical point of view, but also because admixture with a partially drying oil, such as cotton-seed, renders it unsuitable for lubrication and deteriorates its quality for oiling yarns in textile industries. Adulteration with unsaponifiable substances and hydrocarbon oils or waxes would seriously interfere with its use in textile manufactures. It also has been said, that admixture with cotton-seed increases risk of fire from spontaneous combustion in oily waste.

Lard oil does not appear to be of so extensive commercial importance in Europe as it is in this country, where in addition to its use as a lubricant and in textile manufacture, it is still extensively used as an illuminating oil by the United States Lighthouse Board.

Hence, while many other fixed oils, both animal and vegetable, have been investigated in Europe with more or less completeness, one finds in foreign scientific journals few references to chemical examination of lard oil, although lard itself is frequently mentioned. The writer, therefore, thought it worth while to collect together the few scattered references that exist in regard especially to the iodine absorption percentage of lard oil by Hübl's method, and to present the results of a number of examinations made by himself several years ago which have never appeared in print.

Alfred H. Allen (*Analyst*, **13**, 164) found the percentage of iodine absorbed to be seventy-four per cent. in a sample of oil pressed out in his laboratory from lard known to be entirely pure.

J. Campbell Brown stated in a discussion that the percentage iodine absorbed was from seventy-five to eighty per cent. (*Analyst*, **13**, 173.)

Rowland Williams (*Analyst*, **13**, 164) found the percentage to be seventy-three per cent.

T. S. Gladding found it to be 74·60 per cent. (*Analyst*, **14**, 32.)

Thomson and Ballantyne (*Jour. Soc. Chem. Industry*, **9**, 590) found 76·2 per cent. for prime lard oil. On the other hand, Mr. Allen found that an oil *believed* to be pure, which had been kept on hand for several years, absorbed only forty-one per cent. iodine; and he quotes also the result obtained by W. Moeller, of New York, who found in one sample only 47·2 per cent. absorption of iodine. (*Analyst*, **13**, 164).

The figures obtained in my own analyses agree approximately with Mr. Allen's result for pure lard oil pressed out in his laboratory, and with that of Mr. Gladding.

It is difficult to believe that the oils for which Mr. Allen and Mr. Moeller obtained such very low numbers were not adulterated oils and therefore not representative. As lard is composed chiefly of olein and stearine and as pure oleic acid absorbs eighty-five to eighty-six per cent. iodine while pure stearic acid absorbs no iodine at all, commercial stearine less than thirty per cent., and pure lard ranges from fifty-one to sixty-five per cent. with an average for mixed commercial lard of sixty to sixty-two per cent., it is reasonable to expect that lard oil, which is composed chiefly of the olein pressed out of the lard and more or less perfectly freed from the lard stearine, should have a higher absorption number than the whole unpressed lard, and the correct figure would probably be somewhere nearly midway between the figures for lard and for pure olein, or oleic acid. This seems to be really the case in the majority of instances at least. The amount of stearine left in the oil depends upon the temperature at which the pressing of the lard is conducted. I found by experiment that the oil obtained would not begin to chill or congeal until it had reached a temperature several degrees below that at which

it had been pressed out. Thus an oil pressed at 50° F. did not begin to chill or become cloudy until the temperature was below 45° F.

As the percentage of iodine absorbed by cotton-seed oil ranges from 105 to 115 per cent. with an average of 108 to 109 per cent., this average being about the figures usually found; and if we assume, as is probably true, that the correct number for prime lard oil is seventy-two to seventy-four per cent., we have a difference of about thirty-five per cent. between the iodine absorption capacities of lard oil and cotton-seed oil. This affords a sufficient range for calculating the percentage of adulterant used. Even assuming these figures as tolerably constant, I have found it difficult to obtain constant and reliable results showing less than five per cent. of cotton-seed in lard oil in experiments upon known mixtures of these oils, partly on account of the slightest variation of temperature in the laboratory or drafts of cold air from a window seriously affecting the correct reading of the column of iodine solution in the burette which is a nearly saturated solution of iodine and mercuric chloride in ninety-five per cent. alcohol. A difference of 0·1 cc. will cause a variation of nearly 0·5 per cent. of iodine absorbed by the oil as the method is usually conducted. It is absolutely necessary to have the burette protected from drafts of air and to have a delicate and accurate thermometer hung in close proximity to the burette during the whole time of the test or series of tests made in the course of the day, and frequently to observe whether any alteration of temperature has occurred. It is also necessary to use only chloroform of the highest grade of purity for solution of the oil in the flask. I now use only that grade which is sold for purposes of inhalation for medical purposes. It is also now believed that for most oils the time for absorption allowed by Hübl in his original paper is not sufficient, and that for drying, semi-drying and fish oils, the time should be extended to six hours at least, and even eight hours appears to be still better, but that it should not in any case exceed twenty-four hours. I diluted the liquid in the flask (after addition of

potassium iodide solution), with 100 cc. of water instead of 150 cc. as recommended by Hübl, as otherwise the one-quarter litre flasks used became inconveniently full for the proper manipulation if a large excess of iodine remained after the absorption. In the later tests I preferred to leave a large excess of unabsorbed iodine, and this is now considered to be necessary by those who have used this process. When this excess equals the percentage absorbed an increase of the quantity of potassium iodide is necessary up to thirty cc. of the ten per cent. solution instead of ten to fifteen cc. recommended by Hübl. Exactly the same measured quantities of both chloroform and of the potassium iodide solution should be used in the oil tests and in the blank titration tests of the alcoholic iodine solution. The hyposulphite solution should not be kept on hand very long but should be made up fresh every few weeks at longest. The alcoholic iodine solution, when freshly prepared, should stand forty-eight hours before being used in analysis, and only very pure ninety-five per cent. alcohol should be used for preparing it. The flasks used should have glass stoppers accurately fitting, and should be kept at a uniform temperature during the whole experiment. The burettes should be corked at the top when not actually running out solution, or, for the iodine solution at least, it is far better to use the new form of burette, glass stoppered at the top, with a small hole for admission of air, which is closed when not in actual use. The amount of lard oil weighed off for each test was from 0·30 to 0·40 gram, dropped into the same one-quarter litre flask to be used in titrating the oil. Usually, about 0·35 gram was taken, as this seemed to be most convenient.

On comparing the iodine absorption percentages obtained for different oils, it will at once appear that this method alone by no means assures us of the fact that the adulterant is really cotton-seed oil, since a number of other oils, such as rape-seed, sesame and peanut or ground-nut oil have nearly the same iodine absorption numbers as cotton-seed. But the applications of other tests as may seem desirable, such as Bechi's test with an acid alcoholic solution of silver nitrate (omitting the amyl alcohol and rape-seed oil originally pre-

scribed by Bechi); the temperature reaction with ten cc. concentrated sulphuric acid (sp. gr. 1·84) and fifty grams of oil; the melting point of the fatty acids obtained by saponification of the oil, and the elaidin test as described by Allen, will prove conclusively the presence of cotton-seed and almost certainly differentiate the other oils that could be present. The accurate determination of the specific gravity by weighing is generally important, and the presence of any unsaponifiable matter should be noted. The color test by nitric acid may, in some cases, prove useful as also the pure sulphuric acid color tests. All, or nearly all, the other very numerous color tests that have been proposed and used are said to be unreliable or absolutely useless in a mixture of oils of a miscellaneous origin. Other tests may be applied as indications seem to suggest.

My experiments gave results as follows:

I obtained three-pound cans of leaf lard, said to be entirely pure, from each of two well-known lard manufacturers in this city, out of freshly made stock and also a quantity of country lard from a farmer who was accustomed to supply my family with lard. Portions of each of these samples were examined for impurity or adulteration. They all responded satisfactorily to the usual tests for pure unadulterated lard. I did not test the lard by Bechi's test, but subsequently examined the oil by that method. I then pressed out the oil from these separately, using for this purpose a small screw press of the kind made for drugs. The temperature of the room was regulated so that it never exceeded 55°, nor fell below 45° F. Most of the time it stood slightly below 50° F. The pressure was applied gradually, and increased to the utmost that the press was capable of standing. The press was wiped dry after each experiment, and each oil sample was bottled separately.

The samples of lard before expression gave the following results to tests:

	Melting Point.	*Iodine Absorption, Per Cents.*				
Lard No. 1, ...	45° C.	62·9	62·1	61·9	average,	62·3
Lard No. 2, ...	45°	62·65	62 12	62·76	62·42 "	62·49
Country Lard, ...	33°*	59·24	59·42		"	59·33

* This figure is too low.

The country lard was much softer than the others, which fact corresponds with the melting point above given.

These iodine figures correspond nearly with those given by Hübl and others. Hübl gives two determinations in his original paper, viz: 57·6 per cent. and 60·0 per cent. (*vide* also E. W. T. Jones, *Analyst*, **13**, 170). In this country, chemists give a somewhat higher figure for American lard. Thus, R. W. Moore gives 61·9 (*Amer. Chem. Journal*, **6**, 417) and Prof. H. W. Wiley, United States Department of Agriculture, Division of Chemistry, *Bulletin* 13, part 4, p. 418, states that the mean percentage for prime steam lards is 62·86, and for pure lards of other kinds 62·48 per cent. The higher percentage for American lards is accepted by English chemists (*vide Analyst*, **13**, 169). Wiley also states, however, that lard rendered from different parts of the animal gives different iodine absorption percentages, according to the amount of olein contained in it. Thus, a sample of intestinal lard absorbed 57·34 per cent.; leaf lard from the same animal, 52·55 per cent.; foot lard, 77·28 per cent.; and head lard 85·03 per cent. But, as the lard now manufactured in this country is more or less of fat from parts of the whole animal, it has usually an iodine figure closely approximating to 62 per cent. English and other foreign lard is still strictly omentum, or leaf lard, which was the old-fashioned article of this country twenty or thirty years ago.

(1) The lard oil made as above stated from lard No. 1 gave the following percentage absorption of iodine:

74·54; 75·22; 75·95; 74·91; 75·09. Average, 75·14 per cent.

(2) The oil pressed out from lard No. 2 gave results as follows:

73·68; 73·06; 72·52; 72·96; 72·91. Average, 73·03 per cent.

(3) The oil made from the sample of country lard gave:

70·12; 70·45; 70·39; 69·72; 69·33. Average, 70·01 per cent.

Oil No. 1, contained free fatty acid 0·86 per cent., calculated as oleic acid.
" 2, " " 0·49 " " "
" 3, " " 1·35 " " "

Average percentage of iodine absorbed in all three oils together is 72·72 per cent.

In a sample of extra prime lard oil, obtained from a dealer in this city, manufactured in Chicago, but guaranteed to be strictly pure by the Philadelphia firm, gave results as follows for iodine absorbed:

73·10; 75·09; 74·03; 73·88. Average, 74·02 per cent.

This sample had an acidity equivalent to 0·85 per cent. oleic acid. All the above examinations were made about five years ago.

Recently I have re-examined the identical samples of oils above-mentioned to learn if any change had taken place in the iodine absorption percentage during a period of five years in a corked bottle, part of the time exposed to diffused light and part of the time kept in a dark closet, the corks being occasionally removed, the bottles warmed up to liquefy the chilled oil, and portions removed. The oil made from lard No. 1 now gives me iodine absorbed 72·34 and 72·33 in consecutive tests. The extra prime lard oil of Chicago manufacture now gives me iodine absorbed 73·73 per cent.

The acidity for these oils does not appear to have altered much, but has not yet been determined quantitatively.

There seems, therefore, to have been no change of iodine absorbed beyond the limits of experimental error.

PROCEEDINGS

OF THE

ELECTRICAL SECTION,

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting of the Electrical Section, held Tuesday, June 2, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 2, 1891.

Prof. EDWIN J. HOUSTON, President, in the chair.

Present, twenty-six members and visitors.

The minutes of the previous meeting were read and approved.

The treasurer presented bills for printing and clerical work, which were ordered paid when approved.

Four nominations to membership were referred to the committee on admissions. This committee reported three elections since last meeting.

The secretary announced the death of Mr. David Brooks, active member, and upon motion a committee consisting of Messrs. C. Hering, Arnold and Wahl was appointed to draft suitable resolutions, and report them to the Institute as the action of the Section.

Mr. G. H. Almon read a paper on "Lightning Arresters." Referred for publication.

Prof. H. S. Hering concluded the results of his experiments on "The Effect of Atmospheric Pressure on Batteries." This and his former communications on the same subject were referred for publication.

Dr. Wm. H. Wahl exhibited and described an incandescent gas lamp, invented by Mr. Lungren.

There was discussion on this and similar lights by Profs. Houston and Rondinella and Mr. Billberg.

Mr. C. Billberg described a new time switch for electric motors, and exhibited a model in operation.

Mr. Carl Hering exhibited and explained a portable photometer for measuring illumination as well as candle-power.

The Question-Box contained queries concerning the magnetic polarity of drills, the deterioration of copper wire from a long-continued current of electricity, and the proper rise of temperature to allow in a well-designed dynamo. These elicited much interesting discussion.

The meeting then adjourned.

L. F. RONDINELLA, *Secretary.*

DAVID BROOKS.

[At the stated meeting of the Institute, held Wednesday, June 17, 1891, the Secretary presented the following memorial of the late David Brooks, prepared by a special Committee of the Electrical Section. The meeting thereupon approved the memorial, and directed its reference to the Committee on Publications.]

David Brooks, one of the most widely-known electricians of the day, one of the early telegraphers, and for many years an active and useful member of the Franklin Institute, died May 31, 1891, at Germantown, in this city.

Mr. Brooks was born in Brooksvale, Conn., January 26, 1820, and traced his descent directly from Henry Brooks, who emigrated with his family from Cheshire, England, in 1640, and settled in Cheshire, Conn., so named by his children from their native town, and there, and in the portion of the town known as Brooksvale, which bears the family name, the family is still represented.

The name of David Brooks is perhaps more intimately associated with the development and improvement of telegraphic communication than that of any other electrician of America, save Morse, his professional association with this epoch-making branch of electrical engineering dating back to the very beginning of telegraphy in the United States, and continuing actively down to the time of his lamented death.

The principal incidents of his professional career are briefly stated in the following:

After leaving college, at the age of twenty, he became instructor in mathematics, in the United States Navy. In 1845 he left the service and began that association with telegraphy which continued throughout his long and active career.

His first engagement in the telegraphic field was in conjunction with Mr. James D. Reid, to put in service the tele-

graph line between Lancaster and Harrisburg, in this state, which is claimed to have been the first commercial line constructed and operated in the United States, after the successful demonstration of Prof. Morse on his experimental telegraph line between Washington and Baltimore. In the following year, he superintended the construction of the line across the Alleghenies between Pittsburgh and Philadelphia, for the Atlantic and Ohio Telegraph Company. In 1847 he is credited with the invention of the earliest repeating instrument, known as the "Button Repeater," which was used with success.

In 1850 Mr. Brooks was appointed by the United States Court to prepare an opinion as an expert upon the Morse and the Bain systems of telegraphy, which opinion was frequently cited in the course of the litigation that followed.

In 1851, Mr. Brooks was engaged with construction of the first telegraph line in Mexico, between Vera Cruz and the City of Mexico. Upon his return to the States in 1852, he was engaged by the Pennsylvania Railroad Company, as the superintendent of the company's telegraph lines between Philadelphia and Pittsburgh.

In 1854 he became superintendent and manager of the Atlantic and Ohio Telegraph Company. This position he held until 1862, when the company was absorbed by the Western Union Company. He held the position of district superintendent at Philadelphia, with the company, until 1857, when he resigned.

Since then and until his death, he devoted his energies to the development of a number of inventions for the improvement of the telegraph service, which have made his name well known throughout the world.

In 1873 he was named by President Grant as one of the Commissioners of the United States to the Vienna International Exposition, to report upon telegraphic instruments. His report appears in the official publications of the Government on the exhibition, and constitutes one of the most useful and practical contributions of the series.

The most important of Mr. Brooks' inventions relate to the subject of insulation. He was the first to appreciate

and to apply the now universally acknowledged superiority of paraffine for this purpose; and his paraffine insulator for telegraph lines has been widely introduced throughout the United States and in Europe.

He was also among the first to appreciate and to advocate the system of underground lines for telegraph and other electric wires, and his application of the high insulating qualities of the mineral oils, and other liquid insulators for such lines has proved highly successful. The latest improvement in his liquid insulation for underground lines was the substitution of heavy rosin oil for paraffine oil used before. The results were exceedingly encouraging.

Mr. Brooks' services to electric science were recognized early in his professional career by his election to membership in a number of prominent scientific societies at home and abroad. He was elected a member of the Franklin Institute in the year 1867, and was actively interested in the work of the Institute almost to the day of his death.

He was especially interested in the Electrical Section, of which he was one of the founders, and the last technical contribution of his life was made at the Section's stated meeting in May last, when he read a paper "On the Insulating Properties of Oils," which appears in the June impression of the *Journal*.

Personally, Mr. Brooks was a man of great amiability of character, and of commanding presence. By his death the Institute has lost one of its most active and distinguished members, and the world of science one whose inventions have contributed in no small measure to advance the art of telegraphy to its present state.

CARL HERING, *Chairman.*
CRAIG ARNOLD,
WM. H. WAHL,
Committee of the Electrical Section.

BOOK NOTICES.

Hand-book of Calculations for Engineers, Firemen and Machinists. By N. Hawkins, M.E., 336 pp., large 8vo, with numerous illustrations. New York: Theo. Audel & Co., 91 Liberty Street. 1890. (Price, $2.50.)

This book is intended both for reference and instruction in the first principles of the science of steam engineering.

The opening parts teach, first, how to write and read figures; and from this elementary beginning the work proceeds to give the elements of arithmetic, mensuration, geometry, algebra, etc., all illustrated with examples of calculations relating to the every-day problems of the engineer.

Beginning with the elements of mechanics, in which the primary powers are mentioned and briefly described; the lever, wheel and axle, the pulley, and inclined plane are illustrated with figures, examples and descriptions.

Next follow, as general subjects, thermo-dynamics; horse-power, with copious rules for its calculating both of engines and boilers, and of every variety; pumps, with many practical points in their management and calculations; steam, description and figures relating to this main subject, injectors; gravity; strength of materials, with useful tables; the steam boiler; the safety valve, with many rules for ascertaining the safety limit of pressures; the steam engine, with illustrations and calculations, and description of varieties; engine counters; illuminating gas, and how to read the gas meter; tables of melting points of solids; electricity, how to measure and to calculate the numerous problems arising in its applications, with many useful points in its management; table of conductors and insulators of electricity; chimneys; transmission of power by belting and pulleys; the indicator, with illustrations and rules for figuring the diagrams; business points for engineers, and index combined with useful definitions. The work is published in ten parts, in paper covers, and the whole ten parts neatly and handsomely bound in one volume, cloth, making a book for the library 6 x 9 x 1¾ thick. W.

Tables for the Determination of Minerals by Physical Properties, ascertainable with the aid of a few field instruments. Based on the system of Prof. Dr. Albin Weisbach. By Persifor Frazer. 3d edition, entirely rewritten. Philadelphia; Lippincott & Co. 1891.

The third edition of this standard work exhibits numerous evidences of careful revision. The general system of classification by physical peculiarities is retained, but the external characteristics of the mineral species have been more carefully described, and we notice a number of substitutions of new terms, to describe physical characters of structure, and the like, which are decided improvements. A most valuable feature of the tables, which will be duly appreciated alike by student and teacher, is to be found under the column of "Remarks," in which are stated in brief the principal and charac-

teristic reactions, with such specially distinguishing peculiarities which each species may exhibit, together with a list of its associated minerals. This column exhibits the exercise of much care and good judgment. The author has accepted the universally-recognized authority of Dr. Groth for the crystallization and chemical formulæ of minerals. A table of elements is given at the end of the work, based upon the latest revision of the atomic weights made by Prof. F. W. Clarke.

The book bears evidence of having been carefully proofread, since it is notably free from the typographical errors that frequently mar more pretentious works. W. H. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, June 17, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 17, 1891.

JOS. M. WILSON, President, in the chair.

Present, 180 members and thirty-three visitors.

Additions to membership since last report, eight.

The Secretary submitted, on behalf of the Electrical Section, a memorial of the late David Brooks, which was approved by the meeting and referred to the Committee on Publications. [The memorial appears in this impression of the *Journal*.]

Mr. Mortimer McRoberts, of Chicago, read a paper descriptive of the Bevington process of welding metals, illustrating the subject by the exhibition of an extensive exhibit of specimens of copper, brass and aluminum, that had been submitted to the process. After some discussion of the subject of the paper, Mr. S. Lloyd Wiegand moved to refer the invention to the Committee on Science and the Arts for investigation, with the view of recognizing its merits by an award of one of the medals in the gift of the committee should it be found worthy. Carried.

Mr. S. Lloyd Wiegand, on behalf of the Committee on Science and the Arts, presented in abstract the work of the committee in the case of the Vauclain System of manufacturing Forged Car Wheels, as practised at the Baldwin Locomotive Works in Philadelphia.

Mr. F. E. Ives described certain improvements in his process of heliochromic photography, and exhibited a number of such pictures upon the screen, with the aid of the projecting lantern. The pictures attracted much attention and comment.

Mr. John Carbutt, in connection with this subject, spoke as follows:

"Mr. President: 'The demonstration we have just witnessed of the advance made by Mr. Ives in his heliochromic process in being able to show on the screen views direct from nature in all her brilliant colors, I consider by far the most important advance in this difficult subject; as obtained through the aid of photography, and notwithstanding the researches made by European scientists, I know of no results approaching what Mr. Ives has accomplished. I therefore move that the thanks of this meeting be tendered to Mr. Ives for his valuable illustration of heliochromic photography."

The thanks of the meeting were thereupon voted to Mr. Ives.

Mr. W. N. Jennings exhibited a series of interesting pictures of local subjects.

Mr. Carl Hering was chosen as the delegate of the Institute to the International Electrical Exhibition, at present being held at Frankfort-on-the-Main, and to the International Electrical Congress, to be held in connection therewith, and the President and Secretary of the Institute were authorized to issue a suitable document to Mr. Hering, certifying the fact over their signatures and the seal of the Institute.

Mr. Wm. E. Lockwood moved that the courtesies of the Institute be extended to members of the Association of American Railway Master Mechanics (and ladies), at present in session at Wilmington, Del., who may find it convenient to visit Philadelphia, and that the Secretary be instructed to telegraph an official invitation to this effect to the Secretary of the Association. Carried.

Adjourned.

WM. H. WAHL, *Secretary.*

PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW.

For May, 1891.

Prepared under the Direction of the Committee on Meteorology of the Franklin Institute.

Hall of the Franklin Institute,
Philadelphia, May 31, 1891.

TEMPERATURE.

The mean temperature of 52 stations for May, 1891, was 57°.5, which is about 2°.5 below the normal, and 1°.3 below the corresponding month of 1890.

The mean of the daily maxima and minima temperatures 69°.2 and 45°.4 give an average daily range of 23°.8, and a monthly mean of 57°.3.

Highest monthly mean, 61°.0 at Philadelphia, S. O.

Lowest monthly mean, 51°.0 at Wellsboro.

Highest temperature recorded during the month, 93°.0 on the 10th at Carlisle and McConnellsburg.

Lowest temperature 20°.0 on the 4th at Dyberry.

Greatest local monthly range, 64° at Hollidaysburg and Dyberry.

Least local monthly range, 48° at Erie, S. O.

Greatest daily range, 53° at Hollidaysburg on the 10th.

Least daily range, 2° at Wellboro on the 18th.

From January 1, 1891, to May 31, 1891, the excess in temperature at Philadelphia was 258°, at Erie 250°, and at Pittsburgh 222°.

The warmest days of the month were the 10th and 11th. The coldest were the 4th, 5th, 6th, 7th and 17th.

BAROMETER.

The mean pressure for the month, 30.07, is about .07 above the normal. At the U. S. Signal Service Stations, the highest observed was 30.42, at Philadelphia, on the 20th, and the lowest 29.76 at Philadelphia, on the 16th.

PRECIPITATION.

The average precipitation, 2.12 inches for the month, is a deficiency of about one and a quarter inches. The largest totals in inches (including melted snow) were Ligonier, 4.41, and Somerset, 4.16.

The least were Blue Knob, 0.31; Wysox, 0.49, and Lewisburg, 0.67.

Monthly Summary of Reports by Voluntary Observers of T

County.	Station.	Elevation above Sea Level (feet).	Barometer Reduced to Sea Level.			Temperature.								
							Maximum.		Minimum.					
			Mean.	Highest.	Lowest.	Mean.	Highest.	Date.	Lowest.	Date.	Mean of Maximum.	Mean of Minimum.	Mean.	Greatest.
Allegheny,[1]	Pittsburgh,	847	30·100	30·320	29·860	58·8	84	10	34	17	68·9	48·8	30·1	34·0
Bedford,	Charlesville,	1,300	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Berks,[1]	Hamburg,	380	. . .	. . .	. . .	59·0	91	11	33	4, 5	71·5	46·6	24·9	49·2
Berks,	Reading,	280	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Blair,[2]	Altoona,	1,181	. . .	. . .	. . .	62·2	86	11	37	6	72·5	51·8	20·7	34·0
Blair,	Blue Knob,	2,500	. . .	. . .	. . .	56·8	84	10	26	5	. . .	. . .	. . .	. . .
Blair,	Hollidaysburg,	947	. . .	. . .	. . .	58·3	92	10	28	5	73·0	43·4	29·6	53·0
Bradford,	Wysox,	718	30·095	30·300	29·872	55·3	87	10	26	4	68·2	42·9	27·4	48·0
Bradford,	Le Roy,	1,400	. . .	. . .	. . .	56·0	85	10	26	5	64·3	46·3	18·1	31·0
Bucks,	Forks of Neshaminy (29 days),	. . .	. . .	. . .	. . .	58·1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Bucks,	Quakertown,	536	30·050	30·410	29·780	56·5	88	11	31	6	70·0	43·8	26·2	41·0
Cambria,[1]	Johnstown,	1,184	30·109	30·333	29·871	58·3	85	10	33	5, 8	70·9	45·8	25·1	46·0
Cameron,	Emporium,	1,030	. . .	. . .	. . .	50·6	83	9, 10	23	4	70·7	40·8	29·9	46·0
Carbon,[1]	Mauch Chunk (23 days),	550	. . .	. . .	. . .	58·6	90	10	32	6	72·8	45·4	26·4	44·0
Centre,	State College— Agricultural Experiment Station,	1,191	30·023	30·267	29·769	57·1	85	10	31	5, 6	68·5	46·1	22·4	39·0
Chester,	West Chester,	455	30·050	30·418	29·771	58·8	88	11	32	6	68·6	49·6	19·0	30·0
Chester,	Coatesville,	380	. . .	. . .	. . .	58·0	89	10, 11	29	6	70·7	45·6	25·1	44·0
Chester,[1]	Kennett Square,	275	. . .	. . .	. . .	57·6	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Chester,	Phœnixville,	183	30·056	30·422	29·805	58·0	89	11	31	6	70·0	45·7	24·3	37·0
Chester,	Westtown,	350	30·071	30·421	29·720	58·6	88	11	33	6	69·5	49·5	20·0	35·0
Clarion,	Rimersburg,	1,500	. . .	. . .	. . .	56·0	82	29	29	5	65·3	47·4	17·9	35·0
Clarion,	Clarion— State Normal School,	1,530	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Clearfield,	Grampian Hills,	1,450	. . .	. . .	. . .	56·1	78	10, 19	28	5	67·2	45·9	21·3	36·0
Clinton,	Lock Haven,	560	. . .	. . .	. . .	58·3	88	10	31	4, 5, 27	70·6	44·4	26·2	43·0
Columbia,	Catawissa,	491	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Crawford,	Meadville,	1,300	. . .	. . .	. . .	52·5	80	10	27	5	64·5	40·5	24·0	41·0
Cumberland,	Carlisle,	480	. . .	. . .	. . .	59·7	93	10	33	4	73·1	46·3	26·8	41·0
Dauphin,[1]	Harrisburg,	361	30·064	30·373	29·843	59·6	89	10	30	6	70·0	50·0	20·0	32·0
Delaware,	Swarthmore— Swarthmore College,	190	30·041	30·395	29·817	59·4	89	11	30	6	70·4	49·7	20·7	49·0
Erie,[1]	Erie,	681	30·070	30·240	29·840	53·0	80	20	32	5	60·0	45·0	15·0	27·0
Fayette,	Uniontown,	1,000	30·065	30·249	29·855	59·8	83	20, 22	34	5, 7	70·1	45·0	25·1	45·0
Franklin,[1]	Chambersburg— Wilson Female College,	618	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Fulton,	McConnellsburg,	875	. . .	. . .	. . .	59·3	93	10	31	18	72·5	47·6	24·9	48·0
Huntingdon,[1]	Huntingdon— The Normal College,	650	. . .	. . .	. . .	58·2	91	10	30	4, 5	72·7	43·8	28·9	46·0
Indiana,	Indiana— State Normal School,	1,350	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Lancaster,	Lancaster— Franklin and Marshall College,	413	30·048	30·300	29·813	59·0	87	10, 11	32	6	70·3	46·3	24·0	38·0
Lawrence,	New Castle,	932	. . .	. . .	. . .	57·5	87	10	24	17	70·2	40·2	30·1	48·0
Lebanon,	Lebanon,	474	30·074	30·399	29·808	59·2	90	11	32	4	71·6	46·6	25·4	44·0
Lehigh,	Coopersburg,	520	. . .	. . .	. . .	58·5	86	10, 11	34	6	68·3	47·5	20·8	33·0
Luzerne,	Drifton— Drifton Hospital,	1,655	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Luzerne,[1]	Wilkes-Barre,	575	. . .	. . .	. . .	58·7	90	10	31	4, 5, 6	72·2	45·3	26·9	44·0
Lycoming,[1]	Nisbet,	550	. . .	. . .	. . .	57·8	80	20	30	5	. . .	. . .	. . .	. . .
McKean,	Smethport,	1,500	. . .	. . .	. . .	53·7	84	10	24	17	65·8	38·6	27·2	46·0
Mercer,[1]	Greenville— Thiel College,	1,000	30·047	30·342	29·854	54·2	82	10	25	5	66·9	41·3	25·6	39·0
Montgomery,	Pottstown,	130	. . .	. . .	. . .	60·5	90	10, 11	36	4	72·0	50·0	22·0	40·0
Northampton,	Bethlehem,	380	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Philadelphia,[1]	Philadelphia— Signal Office,	117	30·047	30·420	29·760	61·0	90	11	36	6	70·2	51·8	18·3	30·0
Philadelphia,	Philadelphia,	120	30·057	30·432	29·771	61·7	91	11	35	6	71·7	51·7	20·0	31·0
Schuylkill,	Girardville,	1,000	30·010	30·322	29·827	57·3	85	10	31	6	67·6	45·0	22·8	40·0
Snyder,	Selins Grove,	445	30·066	30·343	29·804	59·7	92	10	. . .	. . .	74·1	45·4	28·7	. . .
Somerset,	Somerset,	2,250	. . .	. . .	. . .	53·4	88	10	26	5	67·0	41·0	26·0	46·0
Sullivan,	Eagles Mere,	2,060	30·112	30·359	29·934	52·3	78	9, 10	26	10	60·8	44·7	16·1	34·0
Tioga,	Wellsboro,	1,327	30·034	30·299	29·770	51·0	84	10	23	4	63·6	38·5	24·1	40·0
Union,[1]	Lewisburg,	430	. . .	. . .	. . .	60·4	91	10	31	6	74·3	46·5	27·8	43·0
Warren,	Columbus,	1,410	. . .	. . .	. . .	52·2	84	31	24	13, 17	66·3	38·1	28·2	50·0
Washington,	Canonsburg,	950	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Wayne,	Dyberry,	1,100	. . .	. . .	. . .	52·0	84	10	20	4	66·2	38·8	27·4	43·0
Wayne,	Honesdale,	1,000	. . .	. . .	. . .	54·9	82	10	29	5, 16	67·1	42·8	24·3	40·0
Westmoreland,	Ligonier,	1,750	. . .	. . .	. . .	60·0	87	10	27	18	72·0	49·8	20·4	51·0
Wyoming,[1]	South Eaton	660	. . .	. . .	. . .	55·2	85	10	26	2	67·0	43·4	23·6	. . .
York,[1]	York,	385	30·035	30·401	29·818	59·8	92	10	32	4	73·2	46·5	26·7	46·0

[1] Observations taken at 8 A. M. and 8 P. M. [2] Observations taken at 12 Noon.

THE PENNSYLVANIA STATE WEATHER SERVICE FOR MAY, 1891.

Daily Range.				Relative Humidity.	Dew Point.	Precipitation.			Number of Days.			Wind.			Observers.
												Prevailing Direction.			
Greatest.	Date.	Least.	Date.			Total Inches.	Total Snowfall During Month.	Number of Days Rainfall.	Clear.	Fair.	Cloudy.	7 A. M.	2 P. M.	9 P. M.	
34°0	19	5°0	28	69°3	44°2	3°93	. . .	10	8	8	15	W	W	W	Oscar D. Stewart, Sgt. Sig. Corps.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Miss E. A. G. Apple.
48°5	11	11°0	24	. . .	. . .	2°24	. . .	7	8	14	9	W	W	NW	William Shipe.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Franklin Yager.
34°0	23	10°0	30	41°3	38°3	1°97	. . .	8	. . .	. . .	. . .	. . .	. . .	. . .	Dr. Charles B. Dudley.
. . .	. . .	. . .	. . .	. . .	. . .	1°00	. . .	11	10	13	8	NW	NW	NW	A. H. Boyle.
53°0	10	10°0	24	65°6	45°7	1°95	. . .	8	19	3	9	W	W	E	Prof. J. A. Stewart.
48°0	10	11°0	24	69°2	44°9	.49	. . .	7	13	4	14	E	NW	NW	Charles Beecher.
31°0	19	6°0	21	. . .	. . .	1°18	.40	6	7	14	10	SW	SW	SW	Geo. W. T. Warburton
. . .	. . .	. . .	. . .	. . .	. . .	2°66	. . .	12	11	9	9	N	W	W	J. C. Hilsman.
41°3	11	15°0	30	69°3	47°3	2°56	. . .	10	7	11	13	NW	SW	SW	J. L. Heacock.
46°0	10	13°0	29	81°1	49°2	3°44	. . .	10	6	13	12	. . .	. . .	. . .	E. C. Lorentz.
46°0	10	8°0	24	. . .	. . .	1°06	. . .	5	12	7	12	NW	NW	W	T. B. Lloyd.
44°0	10	10°0	24	. . .	. . .	1°24	. . .	6	7	10	6	NW	NW	NW	John J. Boyd.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	
32°0	19	8°0	21	62°1	42°8	1°94	. . .	6	5	14	12	W	W	W	Prof. Wm. Frear.
30°0	4	7°5	30	65°0	46°7	3°75	. . .	15	12	7	12	NW	W	S	Jesse C. Green, D.D.S.
44°0	10	11°0	15	. . .	. . .	3°64	. . .	11	8	13	10	W	W	W	W. T. Gordon.
. . .	. . .	. . .	. . .	. . .	. . .	1°93	. . .	9	8	11	12	NW	. . .	SE	Benj. P. Kirk.
37°5	11	10°0	26	73°4	49°8	2°74	. . .	13	7	8	16	NW	NW	NW	Knowles Croukey.
38°5	10	7°5	15	. . .	. . .	3°04	. . .	7	5	15	11	W	W	W	Prof. Wm. F. Wickersham.
33°0	27	4°0	24	. . .	. . .	. . .	. . .	11	11	9	11	W	W	W	Rev. W. W. Deatrick, A.M.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	C. M. Thomas, B.S.
36°0	18	2°0	24	. . .	. . .	1°29	.30	8	12	9	10	NW	SW	NW	Nathan Moore.
43°0	10	9°0	28	. . .	. . .	1°87	. . .	3	11	11	10	W	W	W	Prof. John A. Robb.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Robert M. Graham.
41°0	19	9°5	22	77°0	45°0	1°93	1°30	6	13	13	5	NW	N	W	J. & B. H. Metcalf.
47°0	10	5°0	24	79°0	51°0	2°17	. . .	8	9	12	10	S	SW	S	J. E. Pague.
39°0	10	6°0	23	61°4	44°8	1°77	. . .	10	8	8	15	NW	NW	NW	Frank Ridgway, Sgt. Sig. Corps.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	
49°7	9	7°9	16	68°0	49°0	2°12	. . .	7	1	16	14	W	W	W	Prof. Susan J. Cunningham.
57°0	15	6°0	26	73°0	45°0	1°49	. . .	11	11	9	11	NW	NW	NW	Peter Wood, Sgt. Sig. Corps.
45°0	19	3°0	28	. . .	. . .	3°38	. . .	8	13	11	5	. . .	. . .	. . .	Wm. Hunt.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Miss Mary A. Ricker.
48°0	10	8°0	24	63°4	35°8	1°71	. . .	6	12	9	10	N	N	N	Thomas F. Sloan.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	
46°0	10	15°0	6	. . .	. . .	1°89	. . .	7	9	12	10	W	W	W	Prof. W. J. Swigart.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. S. C. Schmucker.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	
38°0	10	11°0	27	72°0	48°5	2°48	. . .	9	6	10	15	NW	NW	NW	Lewis T. Lampe.
48°0	12	11°0	23	. . .	. . .	2°42	. . .	9	13	7	11	NW	E	NW	Wm. T. Butz.
44°4	10	9°7	24	70°2	47°9	3°00	. . .	12	6	17	8	NE	SW	SW	Geo. W. Hayes, C.E.
33°0	11	10°0	24	. . .	. . .	2°25	. . .	9	4	15	12	SE	NW	NE	M. H. Boye.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	H. D. Miller, M.D.
44°0	9	12°0	22	. . .	. . .	1°53	.50	5	16	2	13	NW	NW	NW	A. W. Betterly.
. . .	. . .	. . .	. . .	. . .	. . .	1°80	. . .	4	10	8	13	. . .	. . .	. . .	John S. Gibson, P. M.
46°0	19	8°0	5	. . .	. . .	. . .	. . .	. . .	16	6	9	S	S	S	Armstrong & Brownell.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	
39°5	13	7°7	29	83°0	45°4	3°31	.50	12	11	11	9	NW	NW	NW	Prof. S. H. Miller.
40°0	11	7°0	16	73°0	50°2	2°98	. . .	9	17	5	9	W	W	W	Charles Moore, D.D.S.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Lerch & Rice.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	
30°0	11	7°0	23	63°0	45°0	1°74	. . .	12	9	5	17	NW	NW	NW	Luther M. Dey, Sgt. Sig. Corps.
31°5	20	8°0	24	77°0	50°3	2°01	. . .	12	5	16	10	NW	SW	SW	John Comly.
40°0	10	9°0	24	. . .	. . .	1°80	. . .	11	18	8	5	NW	NW	NW	E. C. Wagner.
. . .	. . .	. . .	. . .	78°6	53°7	1°36	.50	7	12	12	7	SW	SE	SE	J. M. Boyer.
36°0	10	10°0	30	78°3	48°0	4°52	. . .	16	9	10	12	NW	NW	NW	W. M. Schrock.
34°0	9	4°0	6	69°1	43°1	2°67	. . .	5	10	12	9	NW	NW	NW	E. S. Chase.
40°0	15	2°0	28	64°2	38°4	1°25	1°30	5	8	11	12	N	N	N	H. D. Deming.
43°0	10	9°0	24	. . .	. . .	.67	. . .	3	10	17	4	SW	SW	SW	F. O. Whitman.
50°0	13	8°0	5	60°0	36°0	1°58	2°00	7	12	12	7	W	W	W	Wm. Loveland.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	A. L. Runion, M.D.
43°0	4	12°0	21	. . .	. . .	2°27	1°00	8	8	14	9	NW	NW	NW	Theodore Day.
30°0	10	10°0	22	70°4	44°8	1°92	. . .	7	. . .	. . .	. . .	. . .	. . .	. . .	John Torrey.
31°0	20	10°0	23	72°0	50°0	1°41	. . .	6	18	4	9	. . .	. . .	. . .	J. T. Ambrose.
42°0	2	13°0	6	. . .	. . .	1°06	. . .	7	11	11	9	NW	NW	NW	Benj. M. Hall.
46°5	10	11°0	24	74°2	50°9	2°39	. . .	13	13	10	8	NW	NW	NW	Mrs. L. H. Grenewald.

T. F. TOWNSEND, *Observer, Assistant.*

	Altoona.	Bethlehem.	Blue Knob.	Brovers Lock.	Canonsburg.	Carlisle.	Catawissa.	Chambersburg.	Charlesville.	Clarion.	Coatesville.	Columbus.	Coopersburg.	Doylestown.	Dryfton.	Dyberry.	Eagles Mere.	Emporium.	Erie.†	Forks of Neshan'y.	Frederick.	Girardville.	Grampian Hills	Greensville.	Hamburg.	Harrisburg.†	Hollidaysburg.	Honesdale.	Huntingdon.	Indiana.	Johnstown.	Kennett Square.	Lancaster.
1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.02	. .	. .	. .	. .	.09	. .	. .	. .	. .	. .	. .	. .	. .	. .
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3	. .	. .	.01	1 .73	. .	.45	. .	. .	. .	. .	.74	.25	.88	.82	. .	.50	.86	. .	.23	.70	.93	.43	.12	.05	.98	.52	.19	.41	.80	. .	.27	.64	.89
4	.20	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.16	. .	. .	. .	. .	. .	. .	.03	. .	. .	. .	. .	.03	. .	. .	. .	. .	. .	. .	. .	. .	. .
5	. .	. .	.10	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.10	.98	. .	.05	.01	. .	.04	. .	.10	. .	. .	. .	.58	. .	. .	. .	. .	. .
6	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
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11	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	1 .24	. .	. .	. .	. .	. .	. .	. .	.01	. .	.02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
12	. .	. .	. .	.03	. .	. .	. .	. .	. .	. .	.07	. .	.03	.30	. .	. .	. .	. .	. .	.04	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.03	.07
13	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
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15	. .	. .	.12	. .	. .	. .	. .	. .	. .	. .	.22	. .	.17	.35	. .	.10	. .	. .	.16	.11	.17	. .	. .	. .	.07	.16	. .	. .	. .	. .	. .	.37	.25
16	. .	. .	.17	. .	. .	. .	. .	. .	. .	. .	.28	. .	.45	.47	. .	1 .23	.08	. .	.64	.24	.43	. .	. .	. .	.24	. .	. .	1 .14	. .	. .	. .	. .	.23
17	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
18	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
19	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
20	. .	. .	.08	.31	. .	. .	. .	. .	. .	. .	. .	. .	. .	.25	. .	.10	.99	.45	.18	.30	.19	.15	.04	.30	.03	. .	.12	.72	. .	. .	.21	.08	. .
21	.18	. .	.05	. .	. .	.05	. .	. .	. .	. .	. .	.15	.03	. .	. .	.10	.99	.45	.18	.30	.19	.15	.07	1 .16	. .	.12	.19	.06	.25	. .	.88	. .	. .
22	.06	. .	.09	.03	. .	.07	. .	. .	. .	. .	.01	.42	.33	.34	. .	.19	. .	.89	.16	.02	.05	.00	.03	.01	.63	.09	.28	.05	.27	. .	.21	.04	.23
23	1 .19	. .	.05	.06	. .	.31	. .	. .	. .	. .	.83	. .	. .	.05	. .	. .	. .	. .	. .	.01	.02	.08	.22	.21	.02	.29	.25	. .	.53	. .	.28	.20	.12
24	.08	. .	.01	.11	. .	.07	. .	. .	. .	. .	.09	. .	.02	. .	. .	. .	. .	. .	. .	. .	.06	.05	. .	. .	.06	.02	. .	. .	.05	. .	. .	.07	.05
25	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
26	. .	. .	. .	.32	. .	. .	. .	. .	. .	. .	.54	.12	.15	.37	. .	. .	. .	. .	.08	.05	.04	. .	. .	.09	. .	.13	. .	. .	. .	. .	. .	.38	.18
27	. .	. .	. .	. .	. .	.03	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
28	. .	. .	.02	. .	. .	. .	. .	. .	. .	. .	.03	. .	. .	. .	. .	. .	. .	. .	. .	.27	. .	. .	.36	.18	. .	.14	. .	. .	. .	. .	.15	. .
29	.18	. .	.04	.27	. .	1 .17	. .	. .	. .	. .	.17	.06	.19	.48	. .	.07	.46	.17	.02	.01	. .	.27	.14	1 .27	.24	.36	.21	.15	.12	. .	.56	.19	.46
30	.07	. .	.01	. .	. .	.02	. .	. .	. .	. .	.29	.42	. .	. .	. .	.05	. .	.12	.77	. .	. .	.04	. .	.06	. .	.02	.11	.03	.45	. .	.82	. .	. .
31	.17	. .	.01	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.03	.02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.10	. .	. .
	1 .97	. .	.31	2 .15	. .	2 .17	. .	. .	. .	. .	3 .64	1 .58	2 .25	3 .43	. .	2 .27	2 .67	1 .06	1 .49	2 .66	1 .60	1 .80	1 .09	3 .31	2 .24	1 .77	1 .95	1 .92	1 .89	. .	3 .44	1 .93	2 .18

• No record. † U. S. Signal Office.

OBERLIN COLLEGE LIBRARY.

N FOR MAY, 1891.

Lansdale.	Lebanon.	Le Roy	Lewisburg.	Ligonier.	Lock Haven.	Mauch Chunk.	Meadville.	McConnellsburg.	New Castle.	Nisbet.	Ottsville.	Philadelphia.†	Philadelphia.	Phœnixville.	Pittsburgh.†	Point Pleasant.	Pottstown.	Quakertown.	Reading.	Saltsburgville.	Selins Grove.	Smith's Corner.	Somerset.	South Eaton.	State College.	Swarthmore.	Unionstown.	Wellsboro.	West Chester.	Westtown.	Wilkes-Barre	Wysox.	York.
.89	.79	.79	.04	.37	.25	•	.12	.18	•	.20	.89	.50	.66	.78	.22	.80	1.00	.79	.90	.68	.41	.79		.14	.12	.63	.19		.86	.70	.51	.03	.67
						•																											
						•	.10																										
			.04	.05		.01	.05							.01					.01		.04			.08				.15	.02		.04	.04	
.07	.20								.01			.08	.09	.11	.01		.03					.11				.09			.87	.43			
												.05		.03				.04	.01										.07				
																		.22															
.25	.14	.07				.04					.10	.83	.32	.16		.12	.23	.03	.18			.09				.45			.33			.04	.05
.23	.41	.25				.71					.73	.80	.23	.13		.76	.17	.52	.03	.37	.07	.72		.34					.18	.47	.73		.27
	.20	.01			1.10				.25	1.08		.15	.12	.06	.10	.28			.01			.08	.84				.37				.28	.05
.23	.32	.10	.21	.25	1.49	.15	.07	1.18	.25	1.08	.40	.05	.06	.08	.96			.11	.26	.08	.10	.08	.84	.04	.87		.73	.60	.17	.01		.05	.02
.12	.05	.28	.18		.56		.10		.43	.19	.50	.42	.05	.24	.24	.38	.05	.26	.11	.60	.22	.47	.92	.12	.14		.39	.02	.21		.22	.15	.02
.05	.01	.73			.42	.02			.16	.14			.11	.04	.10		.20		.16		.18		.30		.54	.20	.34		.21			.20
		.12											.04	.02	.23		.05	.03	.05	.08						.14			.22	.35	.03		.03
.18	.28	.24				•							.16	.21	.69		.26	.20	.23	.05	.22		.19		.03		.48		.53	.58			.12
																													.04				
		.02													.37														.02	.50			.07
.46	.36	.48	.01		.49		.31	.40	.56	.03		.14	.23	.34	.44	.40	.35	.35	.25	.16	.34	.36	.42	.11	.17	.20	.19	.02	.18				.61
			.70		1.21			.08	.13			.03	.02	.03	.80			.01					.78				.71	.45	.03				.06
														.01													.46						.10
.48	2.66	3.00	1.18	.67	4.41	1.27	1.24	1.93	1.71	2.42	1.20	3.01	1.74	2.01	2.74	3.23	2.94	2.38	2.56	2.21	2.37	1.36	2.81	4.10	1.06	1.94	2.12	3.38	1.25	3.75	3.04	1.53	.49	2.39

T. F. T.

The largest monthly snowfall totals in inches were Columbus, 2·00; Wellsboro, 1·50, and Meadville, 1·50.

WIND AND WEATHER.

The prevailing wind was from the Northwest.

Average number: Rainy days, 8; clear days, 10; fair days, 10; cloudy days, 11.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Hamburg, 22d; Blue Knob, 20th, 22d, 30th; Hollidaysburg, 20th, 22d; Le Roy, 30th; Quakertown, 22d; Johnstown, 20th, 21st, 30th; Emporium, 20th, 31st; State College, 20th; Coatesville, 11th, 22d; Kennett Square, 3d, 22d; Westtown, 11th, 20th; Carlisle, 22d, 26th; Swarthmore, 11th, 20th, 22d, 31st; Huntingdon, 20th, 21st, 22d, 30th; Lancaster, 3d, 11th, 22d; Lebanon, 22d; Pottstown, 3d; Philadelphia, 11th, 20th, 22d; Girardville, 15th, 20th, 24th; Selins Grove, 20th, 22d; Somerset, 21st, 22d, 30th; Wellsboro, 20th, 30th; Lewisburg, 21st; Columbus, 20th, 22d; Ligonier, 20th, 21st, 30th; Meadville, 21st, 30th; York, 11th, 22d.

Hail.—Coatesville, 11th; Phœnixville, 11th; Selins Grove, 22d; Wellsboro, 6th.

Snow.—Hamburg, 6th; Blue Knob, 4th; Hollidaysburg, 6th; Le Roy, 5th, 6th; Johnstown, 6th; Emporium, 5th; Mauch Chunk, 6th; Rimersburg, 5th; Lock Haven, 5th; Carlisle, 6th; Harrisburg, 6th; Swarthmore, 6th; Huntingdon, 6th; Lancaster, 6th; Coopersburg, 6th; Wilkes-Barre, 6th; Greenville, 5th, 6th; Smethport, 4th, 5th, 6th; Philadelphia, 6th; Girardville, 4th, 6th; Selins Grove, 6th; Wellsboro, 5th; Lewisburg, 6th; Columbus, 5th; Dyberry, 6th; Ligonier, 6th; York, 6th; Grampian Hills, 5th; Eagles Mere, 5th.

Frost.—Pittsburg, 4th, 5th, 6th, 7th, 8th, 12th, 13th, 17th; Hamburg, 5th; Blue Knob, 4th, 5th, 7th, 8th, 12th, 13th, 17th, 18th, 19th, 27th; Hollidaysburg, 4th, 5th, 18th; Wysox, 2d, 3d, 4th, 5th, 6th, 8th, 17th, 19th, 27th; Le Roy, 4th, 5th, 6th, 17th, 27th; Quakertown, 2d, 4th, 5th, 6th, 7th, 8th, 10th, 13th, 15th, 16th, 17th, 18th, 19th, 23d, 27th, 28th; Johnstown, 4th, 5th, 8th, 17th, 18th; Emporium, 4th, 13th, 17th, 18th, 27th; State College, 4th; Coatesville, 4th, 5th, 6th; Phoenixville, 4th; Westtown, 6th; Rimersburg, 4th, 5th, 12th, 13th, 17th, 18th, 27th; Lock Haven, 4th, 5th, 6th; Carlisle, 4th; Swarthmore, 6th; New Castle, 4th, 5th, 7th, 8th, 12th, 13th, 17th, 18th, 27th; Lebanon, 4th; Coopersburg, 4th, 5th, 6th; Wilkes-Barre, 4th, 5th, 19th; Nisbet, 4th, 27th; Pottstown, 4th; Selins Grove, 2d, 4th, 5th, 18th, 27th; Somerset, 4th, 5th, 6th, 8th, 17th, 18th, 19th, 28th; Wellsboro, 2d, 3d, 4th, 5th, 6th, 7th, 8th, 12th, 13th, 14th, 17th, 18th, 27th; Lewisburg, 5th; Dyberry, 2d, 4th, 5th, 6th, 7th, 8th, 13th, 14th, 17th, 18th, 19th, 27th, 28th; Honesdale, 1st, 4th, 6th, 17th, 19th, 27th; South Eaton, 2d, 4th, 5th, 6th, 17th; York, 4th, 5th, 17th; Greenville, 5th, 7th, 12th, 13th, 17th, 27th; Columbus, 4th, 5th, 6th, 7th, 8th, 12th, 13th, 14th, 15th, 17th, 18th, 19th, 27th; Meadville, 4th, 5th, 7th, 12th, 13th, 17th, 27th; Grampian Hills, 4th, 5th, 8th, 12th, 17th, 18th, 27th; Eagles Mere, 27th.

Sleet.—Blue Knob, 4th, 6th; New Castle, 5th; Wellsboro, 6th; Ligonier, 4th.

Coronæ.—Blue Knob, 19th; Lebanon, 1st, 2d, 8th, 13th, 14th, 15th, 16th, 17th, 19th, 20th, 21st, 22d; Somerset, 22d.

Solar Halos.—Hollidaysburg, 2d; Le Roy, 1st, 2d, 13th, 25th, 27th, 28th; State College, 16th; Rimersburg, 27th; Huntingdon, 13th; Philadelphia, 13th, 27th; Dyberry, 23d, 25th, 28th; Eagles Mere, 20th, 23d, 27th.

Lunar Halos.—Blue Knob, 18th; Phœnixville, 13th; Carlisle, 13th, 14th; Lancaster, 20th; Somerset, 19th, 21st; York, 19th; Meadville, 16th, 19th, 20th.

Meteors.—State College, 5th.

Parhelias.—Dyberry, 2d; Eagles Mere, 23d.

WEATHER FORECASTS.

Percentage of local verifications of weather and temperature signals as reported by displaymen for May, 1891:

Weather, 85 per cent.
Temperature, 91 per cent.

TEMPERATURE AND WEATHER SIGNAL DISPLAY STATIONS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
C. W. Burkhart,	Shoemakersville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
Capt. A. Goldsmith,	Quakertown.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
New Era,	Lancaster.
D. G. Hurley,	Altoona.
J. E. Forsythe,	Butler.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.

Displayman.	*Station.*
E. C. Wagner,	Girardville.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.
M. Tannehill,	Confluence.
S. C. Burkholder,	Pollock.
Robt. M. Graham,	Catawissa.
Henry F. Bitner,	Millersville.
A. M. Wildman,	Langhorne.
G. W. Klee,	Chambersburg.
A. Simon's Sons,	Lock Haven.
Raftsman's Journal,	Clearfield.
R. C. Schmidt & Co.,	Belle Vernon.
Chas. B. Lutz,	Bloomsburg.
E. C. Lorentz,	Johnstown.
W. M. James,	Ashland.
E. J. Sellers,	Kutztown.
H. M. Kaisinger,	Hartsville.
Foulk & Co.,	Milford.
William Lawton,	Wilmington, Del.
Wister Heberton & Co.,	Germantown.
E. W. Merrill,	North East.
Frank Ridgway,	Harrisburg.
Powell Bros.,	Shadeland.
J. C. McCloskey,	Lock Haven.
Charles Petersen,	Honesdale.
Armstrong & Brownell,	Smethport.
Frank Loomis,	Troy.

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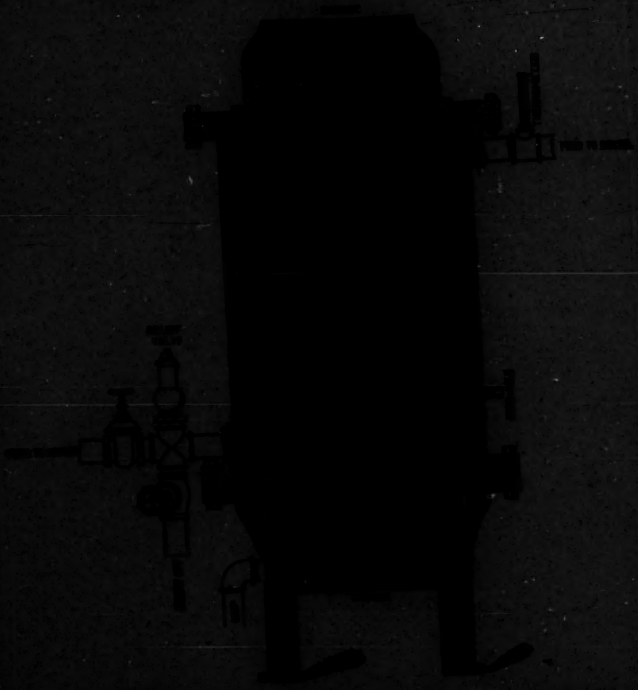

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